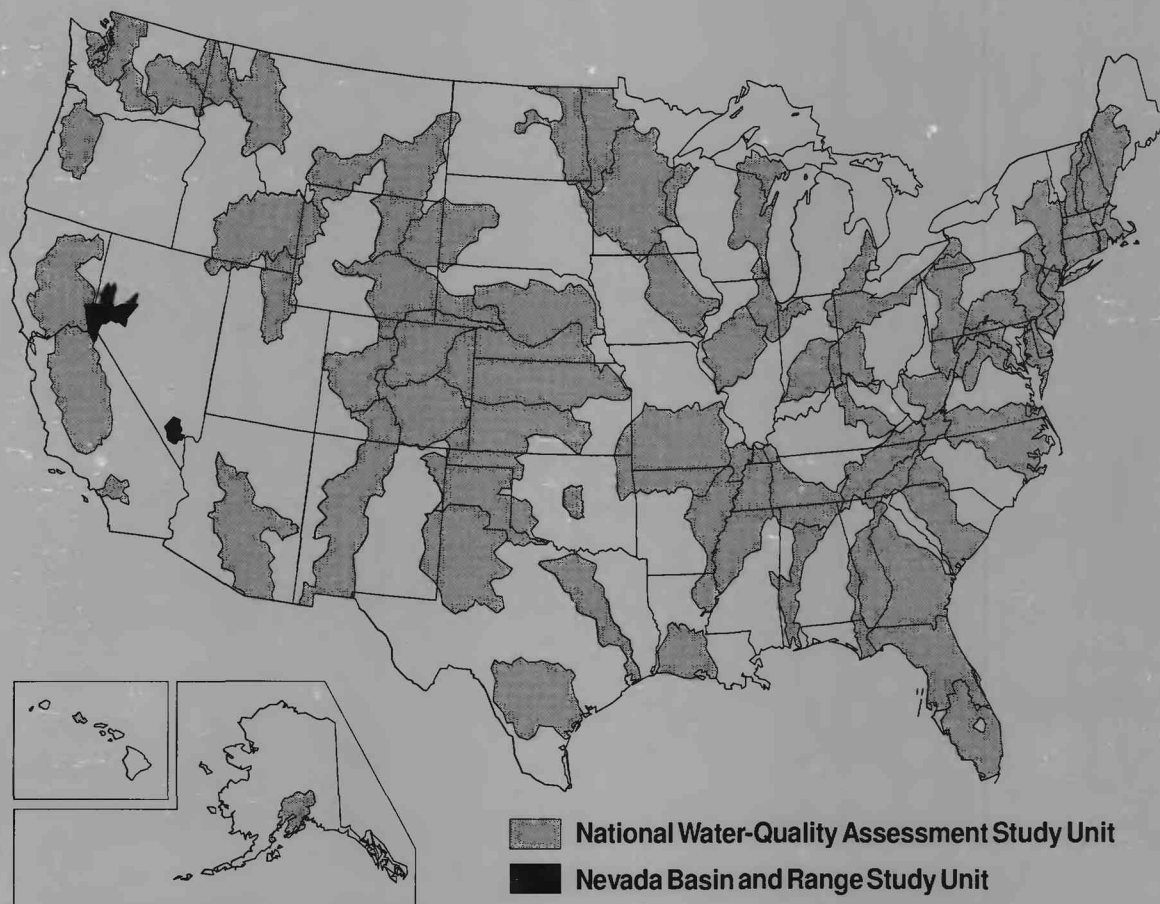


Water-Quality Assessment of the Las Vegas Valley Area and the Carson and Truckee River Basins, Nevada and California—Nutrients, Pesticides, and Suspended Sediment, October 1969-April 1990

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 97-4106



NATIONAL WATER - QUALITY ASSESSMENT PROGRAM

Water-Quality Assessment of the Las Vegas Valley Area and the Carson and Truckee River Basins, Nevada and California—Nutrients, Pesticides, and Suspended Sediment, October 1969-April 1990

By Kathryn C. Kilroy, Stephen J. Lawrence, Michael S. Lico,
Hugh E. Bevans, *and* Sharon A. Watkins

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 97-4106

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Nevada Basin and Range



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GORDON P. EATON, Director

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For additional information
write to:

District Chief
U.S. Geological Survey
333 West Nye Lane, Room 203
Carson City, NV 89706-0866

email: usgsinfo_nv@usgs.gov

<http://wwwnv.wr.usgs.gov>

Copies of this report can be
purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver, CO 80225-0286

FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for specific contamination problems; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional- and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the U.S. Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.
- Describe how water quality is changing over time.

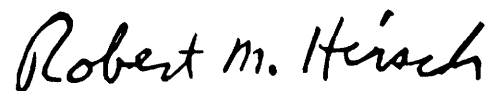
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 60 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 60 study units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.



Robert M. Hirsch
Chief Hydrologist

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CONVERSION FACTORS, VERTICAL DATUM, AND ADDITIONAL ABBREVIATIONS

Multiply	By	To obtain
acre-foot (acre-ft)	0.001233	cubic hectometer
cubic foot per second (ft ³ /s)	28.32	liters per second
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
foot per mile (ft/mi)	0.1894	meter per kilometer
gallon (gal)	3.785	liter
inch (in)	2.540	centimeter
kilopascal (kPa)	100.0	bar
mile (mi)	1.609	kilometer
million gallons per day (Mgal/d)	3.785	million liters per day
part per billion (ppb)	1.000	microgram per kilogram
part per million (ppm)	1.000	milligram per kilogram
pound (lb)	0.4536	kilogram
square mile (mi ²)	2.590	square kilometer
ton (t)	0.9072	megagram
ton per square mile (ton/mi ²)	0.3503	megagram per square kilometer

Temperature: Degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) by using the formula $^{\circ}\text{F} = [1.8(^{\circ}\text{C})] + 32$. Degrees Fahrenheit can be converted to degrees Celsius by using the formula $^{\circ}\text{C} = 0.556(^{\circ}\text{F} - 32)$.

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929, formerly called “Sea-Level Datum of 1929”), which is derived from a general adjustment of the first-order leveling networks of the United States and Canada.

Other abbreviations used in this report:

g/ml	gram per milliliter
kPa	kilopascal
µg/L	microgram per liter
µg/kg	microgram per kilogram
mg/L	milligram per liter
million L/d	million liters per day

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By Kathryn C. Kilroy, Stephen J. Lawrence, Michael S. Lico, Hugh E. Bevans, and Sharon A. Watkins

EXECUTIVE SUMMARY

The U.S. Geological Survey National Water-Quality Assessment Program (NAWQA) is designed to provide long-term, consistent information on water quality that can be used to describe local, regional, and national conditions. The full-scale NAWQA Program, initiated in 1991, includes both study-unit and national synthesis activities. Study-unit investigations provide scientific data and interpretations that will be integrated by national synthesis studies to assess the quality of the Nation's water resources. The Nevada Basin and Range (NVBR) study unit is one of 60 proposed NAWQA study units in the United States. These river-basin-scale areas were selected to represent large proportions of the Nation's water use and population served by public supplies, and the Nation's geographic diversity.

The NVBR study unit includes the Las Vegas Valley area, approximately 1,640 mi² in southern Nevada, and the Carson River Basin (3,970 mi²) and Truckee River Basin (3,230 mi²) in northwestern Nevada and northeastern California. The areas are typical of Basin and Range physiography. Snowfall in high mountains provides streamflow and ground-water recharge in adjacent basins. Unconsolidated basin-fill deposits commonly exceed 1,000 ft in thickness and are principal aquifers in the study unit. The study-unit climate varies from humid continental in the Sierra Nevada where the Carson and Truckee Rivers originate (annual precipitation exceeds 30 in.) to desert in terminal parts of the basins, including the Carson Desert and lower altitudes in Las Vegas Valley, where annual precipitation is less than 5 in.

In 1990, Nevada had the greatest population growth rate and the fourth greatest percentage of population residing in urban areas in the Nation. More than 90 percent of Nevada's population (about 1,090,000 in 1990) resided in the study unit; the Las Vegas Valley area (about 710,000) was the most populous area. In 1990, water use in the study unit was about 1,117,000 acre-ft. Water use in the Las Vegas Valley area was about 317,000 acre-ft; 91 percent was for public supplies. Las Vegas Valley was 79 percent range land, but the 5 percent urban land use has significantly affected water resources. Water use in the Carson River Basin was 538,000 acre-ft in 1990. About 95 percent of the water was used for irrigation, although only 5 percent of the land was used for irrigated agriculture. Water use in the Truckee River Basin was 262,000 acre-ft in 1990. Public supply used about 36 percent of the water, although only 3 percent of the land was urban.

Nutrients, pesticides, and suspended sediments are important water-quality issues in the study unit. Urban runoff and treated sewage effluent contribute these constituents to Las Vegas Wash and the Truckee River. Urban and agricultural activities in the Carson and Truckee River Basins are also sources of these constituents.

Nutrients in Surface Water

The analyses of nitrogen and phosphorus concentrations in the surface waters in the Nevada Basin and Range study unit during October 1969 through April 1990 were limited by the availability of data for only 1 site in the Las Vegas Valley area, 4 sites in the Carson River Basin, 10 sites in the Lake Tahoe Basin, and 9 sites in the Truckee River Basin downstream from Lake Tahoe.

Las Vegas Wash near Henderson was the only site with sufficient data in the Las Vegas Valley area. About 86 percent of the streamflow in 1990 at this site was treated sewage effluent discharged by the Clark County Sanitation District and the City of Las Vegas Water Pollution Control Facility. Median nutrient concentrations were as follows: total nitrogen, 16 mg/L; ammonia, 12 mg/L as N; nitrate, 1.1 mg/L as N; total phosphorus, 1.0 mg/L; and orthophosphate, 0.40 mg/L as P. Total-phosphorus concentrations decreased after 1981 when treatment began removing phosphorus from sewage effluent. Because of the increasing discharge of sewage effluent, annual loads of total nitrogen increased from about 750 tons in water year 1974 to about 2,400 tons in water year 1988.

Nitrogen and phosphorus concentrations in the headwater areas of the Carson River were generally low during the study period. The median concentrations of ammonia for the East Fork Carson River near Gardnerville, Nev., and the West Fork Carson River at Woodfords, Calif., were both 0.03 mg/L as N. Median nitrate concentrations as N were less than 0.10 mg/L at the Gardnerville and Woodfords sites and less than 0.04 mg/L at the West Fork Carson River at Paynesville, Calif.

The median concentrations of total phosphorus at the Gardnerville and Woodfords sites were 0.05 and 0.03 mg/L, respectively. Median concentrations of orthophosphate as P at the three headwater sites were 0.03 mg/L at Gardnerville, 0.02 mg/L at Woodfords, and 0.01 mg/L at Paynesville. Flow-adjusted concentrations of nitrate and orthophosphate decreased slightly during the study period at the Paynesville site.

Nitrogen and phosphorus concentrations and trends are generally different in samples from the Carson River near Fort Churchill than in those from the headwater sites. The median concentration of total nitrogen was 0.77 mg/L. Ammonia concentrations (median, 0.03 mg/L as N) were similar to those at the headwater sites, but nitrate concentrations (median, 0.10 mg/L as N) were higher because of discharge of treated sewage effluent to Carson River during most of the study period.

The median concentration of total phosphorus at the Fort Churchill site was 0.24 mg/L—five to eight times higher than the median concentrations at the headwater sites. The median concentration of orthophosphate at the Fort Churchill site was 0.13 mg/L as P—4 to 10 times higher than the median concentration at the headwater sites.

No long-term trend in flow-adjusted total-nitrogen or nitrate concentrations was observed at Fort Churchill during the study period, but flow-adjusted ammonia concentrations decreased. In addition, flow-adjusted total-phosphorus and orthophosphate concentrations decreased slightly during the study period at the Fort Churchill site. The decreases in the long-term ammonia, total phosphorus, and orthophosphate concentrations probably are a result of decreased discharge of sewage effluent during the late 1970's to mid-1980's. After 1987, decreases in nitrogen and phosphorus concentrations were the result of the cessation of sewage-effluent discharging to the Carson River.

Annual trends in flow-adjusted nitrogen and phosphorus concentrations were observed at the Paynesville and Fort Churchill sites. At the Paynesville site, flow-adjusted orthophosphate concentrations were slightly higher in the summer. Total-nitrogen, ammonia, nitrate, total-phosphorus, and orthophosphate concentrations were lower in the summer at the Fort Churchill site. These trends indicated that biological activity (nutrient uptake by algae and aquatic macrophytes) affected nitrogen and phosphorus concentrations at the Fort Churchill site; biological activity increases as water temperature increases.

Nitrate and orthophosphate concentrations decreased as streamflow increased at the Paynesville site. Nitrate and orthophosphate at the Fort Churchill site increased and then decreased as streamflow increased, a "flush" response. Total-nitrogen and total-phosphorus concentrations increased as streamflow increased at the Fort Churchill site, whereas ammonia concentrations were nearly constant. Annual total-nitrogen and total-phosphorus loads at the Fort Churchill site averaged 370 and 90 tons, respectively, during the study period. Loads varied with streamflow and were largest during May and June, when streamflow was highest, because of snowmelt.

In general, nitrogen and phosphorus concentrations were relatively dilute in the streams analyzed in the Lake Tahoe Basin. Median concentrations of total nitrogen ranged from 0.34 to 0.63 mg/L. Median concentration of ammonia ranged from 0.003 to 0.009 mg/L as N. Median concentrations of nitrate ranged from 0.004 to 0.040 mg/L as N. The concentrations of phosphorus species also were low with median total-phosphorus concentrations ranging from 0.03 to 0.05 mg/L and median orthophosphate concentrations ranging from 0.003 to 0.020 mg/L as P.

Few samples were analyzed for total nitrogen during the study period and trend analysis was not possible. At Third and Incline Creeks, the data were adequate for evaluating trends in ammonia, nitrate, total-phosphorus, and orthophosphate concentrations. Samples collected during water years 1970-73 at Third Creek had higher flow-adjusted concentrations of ammonia and orthophosphate than samples collected during water year 1988 through April 1990. Incline Creek had higher flow-adjusted concentrations of ammonia and total phosphorus during water years 1970-73 than during water year 1988 through April 1990. Flow-adjusted nitrate concentrations were higher at Third Creek during the late 1980's than during the early 1970's. The difference in nutrient concentrations for samples from Third and Incline Creeks during the two sampling periods may be the result of urban development at Incline Village during the early 1970's. Avalanches in the Third Creek watershed in 1986 might have contributed to the higher nitrate concentrations during the late 1980's.

Although data were limited for evaluating annual trends in the Lake Tahoe Basin, concentrations of nitrate were highest in late winter and early spring for Meeks, and flow-adjusted concentrations were highest in late winter and early spring for Third, Incline, and Blackwood Creeks. Flow-adjusted concentrations of total phosphorus were highest in late winter for Third and Incline Creeks.

Nutrient relations to streamflow differed. For example, Incline Creek showed an increase in ammonia, nitrate, total-phosphorus, and orthophosphate concentrations as streamflow exceeded the 70th percentile. Samples from Third Creek showed a similar but less dramatic response in total-phosphorus concentrations; however, ammonia and nitrate concentrations at Third Creek rapidly increased then decreased as streamflow increased, a "flush" response. Blackwood Creek nitrate concentrations also showed a "flush" response, but orthophosphate concentrations decreased slightly as streamflow increased. The mean annual total-nitrogen load for Third Creek was about 6.5 tons and the mean annual total-phosphorus load was about 1.7 tons. Loads were highest during May and June, when streamflow was highest.

In the Truckee River Basin downstream from Lake Tahoe, nutrient concentrations generally increased in a downstream direction. At Farad, median concentrations of nutrients were as follows: 0.36 mg/L for total nitrogen, 0.02 mg/L as N for ammonia, 0.06 mg/L as N for nitrate, 0.02 mg/L for

total phosphorus, and less than 0.01 mg/L as P for orthophosphate. The median concentrations at Farad were similar to those measured in Sagehen Creek, a USGS Hydrologic Benchmark Network Station.

Nutrient concentrations are elevated downstream from the TMWRF effluent discharge point. The median concentrations of nutrients for Lockwood were as follows: total nitrogen, 1.4 mg/L; ammonia, 0.51 mg/L as N; nitrate, 0.20 mg/L as N; total phosphorus, 0.19 mg/L; and orthophosphate, 0.05 mg/L as P.

Flow-adjusted ammonia concentrations have decreased slightly at Nixon since the 1980's, probably as a result of ammonia removal at the TMWRF. Nitrate concentrations at Sparks and Nixon increased, but few samples have been collected at Nixon since water year 1987. Flow-adjusted orthophosphate concentrations decreased during 1970-84 at Farad, but have remained nearly constant since 1985. Flow-adjusted orthophosphate concentrations have decreased at Sparks and Nixon. Flow-adjusted total phosphorus has decreased at Nixon.

Annual trends in flow-adjusted nutrient concentrations were observed at all four sites on the Truckee River (Farad, Sparks, Lockwood, and Nixon). At Farad and Sparks, nitrate concentrations were highest in the winter, probably because of decreased biological activity; total-phosphorus concentrations were highest during the summer, probably because of runoff from thunderstorms. At Lockwood, nitrogen and phosphorus species concentrations were highest in summer. At Nixon, nitrogen and phosphorus species were highest in winter. High concentrations of nitrogen and phosphorus species at Lockwood during the summer may be due to the dominance of treated effluent from the TMWRF during this low-flow period.

Relations among nutrient concentrations and streamflow were different at each site on the Truckee River. Total-nitrogen and nitrate concentrations at Farad decreased as streamflow increased (dilution); ammonia concentrations did not change. Total nitrogen and ammonia increased with increasing streamflow near Sparks and Nixon. Nitrate concentrations increased rapidly near Nixon and Sparks and then decreased, a "flush" response. Total-phosphorus concentrations at Farad and Sparks did not change with streamflow. Total-phosphorus and orthophosphate concentrations at Nixon increased, then decreased as streamflow decreased.

The mean annual load of total nitrogen transported by the Truckee River near Nixon was about 900 tons during the study period. The mean annual

total-phosphorus load transported by the Truckee River near Nixon was about 210 tons. The greatest loads of total phosphorus were transported during January through June when streamflow was high.

Nutrients in Ground Water

The NVBR NAWQA study unit comprises three areas—the Las Vegas Valley area and the Carson and Truckee River Basins. Protection of the quality of drinking-water supplies in these areas is becoming increasingly important as the population increases.

Nutrient species (orthophosphate, ammonia, and nitrate) are important contaminants that can be introduced into ground water by land-use activities. Some of the activities that could contribute nutrients to the ground water are urban and agricultural fertilization of lawns and crops, leaking sewage-collection systems, animal wastes, land application of treated sewage effluent, and septic-system discharge. Shallow aquifers are especially vulnerable because of the potential for downward movement of contaminants through the unsaturated zone to the water table. Natural sources of nitrogen have been shown to cause high nitrate concentrations in ground water at the Gilcrease Ranch northwest of Las Vegas. These natural sources, which include evaporite deposits and organic matter, may cause elevated nitrate concentrations elsewhere in the study unit as well.

Using ground-water-quality analyses for 363 wells sampled during water year 1970 through April 1990, nutrient concentrations from each hydrographic area were compared by selected categories. Categories are hydrologic setting as either headwater or basin; land use near the well as urban, agriculture, range, or wetland; and depth of well as either shallow (50 ft or less below land surface) or deep (greater than 50 ft).

In general, nutrient concentrations in ground water from the shallow aquifers were significantly higher statistically in basin areas than in headwater recharge areas. Orthophosphate concentrations in the shallow aquifers were significantly higher in basin areas than in headwater areas (medians, 0.29 and 0.034 mg/L as P, respectively). Ammonia concentrations in ground water from the shallow aquifers were significantly higher in the basin areas than in headwater areas (medians, 0.20 and 0.035 mg/L as N, respectively). Nitrate concentrations in ground water from the shallow aquifers were significantly higher in basin areas than in headwater areas (medians, 1.0 and 0.1 mg/L as N, respectively).

In the deep aquifers, orthophosphate concentrations in the basin and headwater areas (medians, 0.02 and 0.03 mg/L as P, respectively) were not significantly different. Ammonia concentrations in samples from the deep aquifers were significantly higher in basin areas than in headwater areas (medians, 0.06 and 0.01 mg/L as N, respectively). Samples from deep aquifers had nitrate concentrations in basin and headwater areas that were not significantly different (medians, 0.36 and 0.33 mg/L as N, respectively).

The type of land use potentially can have effects on the quality of ground water. For this report, land use was divided into four categories—urban, agricultural, range, and wetland areas. Orthophosphate concentrations in ground water beneath agricultural areas were significantly higher than those from all other areas. Ammonia concentrations in ground water beneath urban, agricultural, and range areas were not significantly different; but were significantly higher in wetland areas.

Land use has the potential to affect shallow aquifers more readily than generally protected deep aquifers. Because of this vulnerability, data from shallow and deep wells were analyzed separately. Orthophosphate concentrations in ground water from the shallow aquifers were significantly higher in agricultural areas (median, 0.22 mg/L as P) than in urban and range areas (medians, 0.04 mg/L). Ammonia concentrations in the shallow aquifers were not significantly different in urban and range areas (medians, 0.10 and 0.08 mg/L as N, respectively). Nitrate concentrations in shallow aquifers were significantly higher in urban areas (median, 2.8 mg/L as N) than in agricultural (median, 0.46 mg/L) and range areas (median, 0.04 mg/L). Agricultural and range areas had nitrate concentrations that were not significantly different.

In water samples from deep aquifers, orthophosphate concentrations were significantly higher in agricultural areas (median, 0.05 mg/L as P) than in urban and range areas (medians, 0.03 mg/L). Ammonia concentrations were significantly higher in deep samples from agricultural areas (median, 0.02 mg/L as N) than in samples from urban areas (median, 0.01 mg/L).

Water samples from shallow aquifers in agricultural areas had significantly higher concentrations of orthophosphate (median, 0.22 mg/L as P) than samples from deep aquifers (median, 0.05 mg/L). In urban and range areas, water samples from shallow aquifers had higher concentrations of dissolved ammonia (medians, 0.10 and 0.08 as N, respectively) than those from deep aquifers (medians, 0.01 mg/L). In urban and

agricultural areas, dissolved nitrate concentrations (medians, 2.8 and 0.46 as N, respectively) were higher in samples from shallow aquifers than from deep aquifers (medians, 0.37 and 0.13, respectively).

Because each hydrographic area has unique hydrologic and geologic characteristics, statistical analyses of nutrient data were completed for each area. For some areas, adequate data were not available to apply the statistical tests used to determine whether the distributions are different or similar.

In the Las Vegas Valley area, orthophosphate, ammonia, and nitrate concentrations were not significantly different in water samples from aquifers beneath urban and range areas.

In the Carson River Basin, orthophosphate concentrations were significantly higher in ground water beneath agricultural areas than in urban and range areas. Urban land-use areas had ground water with ammonia concentrations that were significantly lower than those in agricultural and range areas. Nitrate concentrations were not significantly different in ground water beneath urban, agricultural, and range areas.

In the Truckee River Basin, orthophosphate concentrations in samples from ground water beneath urban areas were significantly higher than those from range areas. Ammonia and nitrate concentrations were not significantly different in ground water from urban and range areas.

Nitrate is the only nutrient species discussed in this report that is regulated by the State of Nevada for drinking water. Nitrate, in high concentrations, can be toxic to humans, especially infants. "Blue-baby" syndrome in infants is the most common effect of high nitrate concentrations. Of the 363 wells where water samples were collected, samples from only 14 wells exceeded the maximum contaminant level (MCL; 10 mg/L as N) for nitrate. Six of the water samples that exceeded the MCL were from the Las Vegas Valley and eight were from the Carson River Basin. Four of these wells (all in the Carson River Basin) are used as domestic drinking-water supplies.

The source of nitrate in the samples exceeding the MCL cannot be determined with the present data. Nitrate contamination of ground water can occur in areas where septic systems are in use. Many rural parts of the study unit use septic systems for waste disposal. Carson City is requiring the abandonment of septic systems in the southeastern part of the city because of nitrate contamination of private domestic-supply wells.

Pesticides in Surface and Ground Water

Pesticide contamination of water resources depends on pesticide characteristics, pesticide use, site characteristics, flow regime, and climate. However, because many of the pesticides used in Nevada have not been sampled for, knowledge of water-resources contamination is limited. Most sampling strategies were based on the high toxicity and carcinogenicity of compounds to mammals, particularly humans, and some strategies were designed to sample for compounds that are toxic, mutagenic, or cause reproductive failure of aquatic life. The data are treated qualitatively because differences in the purposes for sampling, sampling and analytical methods, and matrices sampled make a more rigorous comparison difficult.

Approximately 190 pesticides were used in Nevada during 1970-90. Although the information on pesticide use is somewhat incomplete, it highlights those compounds that have been used most heavily. The major reported use is agricultural and urban use is secondary. Herbicides with the highest reported usage in Nevada are 2,4-D; 2,4-DB; atrazine; chlorpropham; dinoseb; endothall; hexazinone; metribuzin; and simazine. Insecticides are carbofuran, dimethoate, endosulfan, malathion, methidathion, naled, and parathion; however, no information was available for discontinued substances such as *p,p'*-DDT homologues. Temporal variations in pesticide use were irregular, possibly because of market, climatic, and biologic cycles.

Twenty years of analysis have shown pesticide contamination of surface- and ground-water resources in the study unit. Of the 190 pesticides with use reported in Nevada, 68 have been analyzed for and 34 have been detected. The pesticides and insecticides that were detected the most were those that were sampled for the most. The pesticides 2,4-D; 2,4,5-T; 2,4,5-TP; aldrin; chlordane; *p,p'*-DDD; *p,p'*-DDE; *p,p'*-DDT; dieldrin; heptachlor; and lindane were detected in surface water of all three basins. Concentrations of chlordane, endrin, heptachlor, heptachlor epoxide, lindane, and toxaphene exceeded MCL's. These pesticides and aldrin; *p,p'*-DDD; *p,p'*-DDT; diazinon; dieldrin; endosulfan; and malathion exceeded the criteria for protection of freshwater aquatic organisms.

Data were available for 291 sites within the study unit. The distribution of pesticides in water samples suggests that surface and ground water in Las Vegas Valley area (pl. 1) were more affected

(64 and 43 percent of sites sampled, respectively) than the Carson and Truckee River Basins. The Carson and Truckee River Basins (pl. 2) have relatively few pesticides in surface water (7 and 6 percent of the sites sampled, respectively) and ground water (18 and 2 percent of the sites sampled, respectively). Surface- and ground-water sites in basin areas were more affected (50 and 33 percent, respectively) than headwater areas (3 and 8 percent, respectively).

Temporal variations were examined in data for surface water, fish, and at sites in Las Vegas Wash, Lake Mead, and on the Truckee River. Diazinon and 2,4-D concentrations in water samples from Las Vegas Wash near Boulder City appear to have increased from 1974 to 1980 and lindane concentrations appear to have decreased. Concentrations of *p,p'*-DDD; *p,p'*-DDE; *p,p'*-DDT; and dieldrin appear to have declined in fish-tissue samples from Truckee River near Fernley during 1970-84.

Suspended Sediment in Surface Water

Suspended sediment in streams and rivers is a water-quality issue that is important to both land and water resources. Suspended-sediment transport rates are directly related to rates of soil erosion in watersheds and to rates of sedimentation in downstream areas. Sediment erosion and deposition can impair aquatic habitats, and increased rates of sedimentation in channels and impoundments can increase flooding and decrease storage capacities of impoundments.

Environmental factors and human activities can affect suspended-sediment transport. The amount of runoff from snowmelt in the Sierra Nevada is an important natural factor in the study unit. Human activities in the study unit that have the potential for affecting suspended-sediment transport include urbanization, agriculture, and mining.

Data for long-term suspended-sediment sites (water year 1970 through April 1990) in the USGS NWIS and the U.S. Environmental Protection Agency STORET data bases were evaluated. Although 36 long-term suspended-sediment sites were operated in the study area by the USGS and the U.S. Forest Service, only USGS sites were used in this study because continuous streamflow records also were available. Data for the USGS sites were evaluated to determine their temporal and hydrologic representativeness. Those stations that were representative of water year 1980 through April 1990 conditions were selected for

analysis. Only seven stations met the criteria of temporal and hydrologic representativeness—Las Vegas Wash near Boulder City, Carson River near Fort Churchill, Upper Truckee River at South Lake Tahoe, Third Creek near Crystal Bay, Trout Creek near Tahoe Valley, Sagehen Creek near Truckee, and Truckee River near Nixon.

The suspended-sediment concentrations were seasonally normalized to remove bias introduced by most of the samples being collected during spring runoff, to obtain a more representative data set for the selected sites. Statistical summaries of suspended-sediment concentrations for streamflow deciles show the direct relation of these two variables.

An areal evaluation of statistical summaries of suspended-sediment concentrations for the selected sites with respect to land use indicates that (1) the lowest concentrations of suspended sediment were measured in Sagehen Creek near Truckee, possibly owing to the absence of urban and agricultural land use in the basin, (2) the low concentrations of suspended sediment in the Truckee River near Nixon could be a result of the presence of regulated impoundments in its watershed (land use is 11.6 percent open water), (3) the Carson River near Fort Churchill drains the largest agricultural area (6.7 percent) and had the second highest 75th- and 90th-percentile concentrations of suspended sediment, and (4) the highest concentrations of suspended sediment were measured in Las Vegas Wash near Boulder City. Although the total drainage area of Las Vegas Wash only has about 5 percent urban land use, nearly all streamflow at this site comes from the urban area.

Temporal variations in suspended-sediment concentrations were mainly caused by variations in streamflow rates. Concentrations were highest in the spring when streamflow was greatest owing to snowmelt runoff, and lowest in the summer during low streamflow conditions. Flow in Las Vegas Wash was primarily from treated sewage effluent and had little or no relation to season. A recent investigation showed no trends in suspended-sediment concentrations for the Carson River near Fort Churchill or the Truckee River near Nixon during water years 1980-89.

Adequate regression models for computing suspended-sediment loads were developed for Carson River near Fort Churchill, Third Creek near Crystal Bay, Sagehen Creek near Truckee, and Truckee River near Nixon. Suspended-sediment loads published by the USGS California District were used for long-term

suspended-sediment stations on the Upper Truckee River at South Lake Tahoe, Blackwood Creek near Tahoe City, and Ward Creek at Highway 89. Variation in the transport of suspended sediment principally was caused by variation in streamflow. The largest median annual loads of suspended sediment and rates of streamflow were in the Carson River near Fort Churchill (180,000 tons and 315,000 acre-ft) and the Truckee River near Nixon (200,000 tons and 332,000 acre-ft). The largest annual loads and rates of streamflow during water years 1980-89 were during 1980, 1982-84, and 1986. Seasonal transport rates generally were greatest during the spring snowmelt runoff and least during the summer low flow.

Median annual suspended-sediment yields were computed by dividing median annual loads by drainage areas. The site with no urban or agricultural land use, Sagehen Creek near Truckee, had the smallest yield of suspended sediment (12 ton/mi²). The site with the most urbanization, Third Creek near Crystal Bay (9.9 percent) had the largest yield of suspended sediment (630 ton/mi²). The Truckee River near Nixon had an annual suspended-sediment yield of 110 ton/mi². The Carson River near Fort Churchill, which has the most agricultural land use (6.7 percent), had an annual suspended sediment yield of 140 ton/mi².

THE NEVADA BASIN AND RANGE NATIONAL WATER-QUALITY ASSESSMENT PROGRAM

By Kathryn C. Kilroy

INTRODUCTION

The U.S. Geological Survey, which has collected water-resource data since 1879, has developed a new approach to investigate the effects of natural factors and human activities on the quality of the Nation's water resources. The National Water-Quality Assessment Program (NAWQA) is designed to provide long-term, consistent information on national water-quality issues at local study-unit scales that can be integrated by national synthesis studies to describe regional and national conditions. The goals of the NAWQA Program are to:

- Provide a nationally consistent description of current water-quality conditions for a large,

representative part of the Nation's surface- and ground-water resources;

- Define long-term trends in water quality; and
- Identify, describe, and explain, as possible, the major factors that affect the observed water-quality conditions and trends.

The full-scale NAWQA Program, initiated in 1991, will eventually include up to 60 river-basin-scale study units, distributed throughout the Nation, that include large proportions of the Nation's water use and population served by public water supply.

Nevada Basin and Range Study Unit

The Nevada Basin and Range (NVBR) study unit includes three hydrographic basins and adjacent areas: (1) the Las Vegas Valley area, (2) the Carson River Basin, and (3) the Truckee River Basin. The Las Vegas Valley area is in southern Nevada (pl. 1) and the Carson and Truckee River Basins are in northwestern Nevada and northeastern California (pl. 2). The basins were selected for investigation because they (1) contain more than 90 percent of Nevada's population; (2) include geologic features, climate, vegetation, and hydrology representative of Basin and Range physiography; (3) include areas where rapid urban and suburban population growth has increased competition for limited water supplies; and (4) contain various natural- and human-caused water-quality problems. Ground-water quality in the Carson River Basin was investigated as part of the pilot NAWQA Program.

Purpose and Scope of the Overall Report and of This Section

The purpose of this report is to describe the presence and transport of nutrients, pesticides, and suspended sediment in water resources of the NVBR study unit, using available data. The scope of this report is to:

- Assemble and evaluate available analyses for nutrients (total phosphate, orthophosphate, total nitrogen, ammonia, and nitrate), pesticides (herbicides, insecticides, and their degradation products), and suspended sediment;
- Summarize available data and determine, where possible, the spatial and temporal distribution and transport of nutrients, pesticides, and sediment;

- Identify areas of concern, and ascertain relations to human and natural factors (including land use, geographic features, and hydrogeologic conditions).

The geographic scope of this report covers several hydrographic areas and includes the Las Vegas Valley Hydrographic Area¹ and part of the Black Mountains Hydrographic Area. The Carson River Basin contains the Carson Valley, Eagle Valley, Dayton Valley, Churchill Valley, and Carson Desert Hydrographic Areas. The Truckee River Basin includes the Lake Tahoe Basin, Truckee Canyon Segment, Washoe Valley, Pleasant Valley, Truckee Meadows, Sun Valley, Spanish Springs Valley, Warm Springs Valley, Tracy Segment, Dodge Flat, Pyramid Lake Valley, and Winnemucca Lake Valley Hydrographic Areas. The Fernley Hydrographic Area is included in the study unit because the Truckee Canal, which diverts water from the Truckee River to Lahontan Reservoir in the Carson River Basin, flows through it.

The data used were primarily those available on computerized data bases for October 1969 through April 1990 (or water year 1970 through April 1990). The data bases include the NWIS of USGS, information collected by the Nevada Department of Conservation and Natural Resources and Desert Research Institute that is maintained as a separate data base (QWDATA3) within NWIS, and STORET of the USEPA. The pesticide analyses also include data from the Nevada State Health Laboratory. Selected surface- and ground-water sites where nutrient, pesticide, and suspended-sediment data have been collected in the NVBR study unit are listed in appendixes A and B and shown on plates 1 and 2 at the back of this report.

This section of the report describes the hydrologic and environmental settings of the NVBR study unit and presents a discussion of water-quality issues. These topics are discussed for major hydrologic areas in the study unit, including the Las Vegas Valley area, the Carson River Basin, and the Truckee River Basin.

¹Formal hydrographic areas in Nevada were delineated systematically by the U.S. Geological Survey and Nevada Division of Water Resources in the late 1960's for scientific and administrative purposes (Rush, 1968; Cardinalli and others, 1968). The official hydrographic area names, numbers, and geographic boundaries continue to be used in U.S. Geological Survey reports and Nevada Division of Water Resources administrative activities.

NEVADA BASIN AND RANGE HYDROLOGIC AND GEOGRAPHIC SETTINGS

The NVBR study unit includes approximately 1,640 mi² in the Las Vegas Valley area (pl. 1) and 7,200 mi² in the Carson and Truckee River Basins and adjacent areas (pl. 2). The dry sunny climate causes large evaporative losses in all three basins. Surface-water flow in the three basins has been heavily affected by human activities during the 20th century, which caused changes in the quality and quantity of water.

Hydrologic Setting

The principal drainage in the Las Vegas Valley area is Las Vegas Wash, which flows only in the lower part of the basin from Las Vegas downstream to Lake Mead on the Colorado River. Flow in the wash is principally composed of tertiary treated sewage effluent with some return flow from landscape irrigation. Although Las Vegas Valley is underlain by carbonate rocks with moderately high hydraulic conductivity, the principal aquifers are composed of basin fill. Recharge areas are in mountains to the north and northwest; discharge areas are in lowlands in the southeastern part of the basin.

The Carson and Truckee River Basins, in northwest Nevada and northeast California, are contiguous closed basins whose axes trend northeastward. The Carson and Truckee Rivers flow northeastward from headwater areas in the Sierra Nevada and terminate in interior lowlands: the Carson Desert and Pyramid Lake, respectively. The rivers have perennial flow throughout most of their length. Principal basin-fill aquifers receive recharge from snowmelt in the Sierra Nevada and other high mountain ranges. These aquifers are in most major valleys including Carson Valley, Eagle Valley, Churchill Valley, Carson Desert, Lake Tahoe Basin, Washoe Valley, and Truckee Meadows.

Las Vegas Valley Area

The Las Vegas Valley area encompasses approximately 1,640 mi² in southeastern Nevada (pl. 1). Altitudes range from about 11,900 ft in the Spring Mountains to the west to about 1,200 ft at the mouth of Las Vegas Wash. The valley trends northwestward and is approximately 50 mi long and 30 mi wide.

The climate of the Las Vegas Valley area ranges from subhumid continental in higher altitudes of the Spring Mountains, where average annual precipitation approaches 20 in., to low-latitude desert at lower altitudes, where average annual precipitation is about 4 in. (Covay and others, 1996). Headwater areas in the Spring Mountains and the Sheep Range do not produce sufficient runoff to sustain streamflow. Unconsolidated basin-fill deposits constitute the principal aquifers in the Las Vegas Valley.

Prior to development in Las Vegas Valley, Las Vegas Wash had been a perennial stream in its lower reaches, but it became dry because of extensive ground-water withdrawals during the early 20th century. Las Vegas Wash now flows perennially downstream from Las Vegas, primarily because of treated sewage effluent and return flow from landscape irrigation. The average streamflow of Las Vegas Wash near Henderson (site 13, pl. 1 and app. A) during 1970-88 was approximately 60 ft³/s (Covay and others, 1996). Most of the water used in the Las Vegas Valley area comes from Lake Mead and is supplemented with ground-water withdrawals from Las Vegas Valley.

Most of the aquifer recharge areas in Las Vegas Valley are on the flanks of the higher peaks in the Spring Mountains and Sheep Range. The mountain ranges are composed of carbonate bedrock (limestone and dolomite) with some shale and other clastic rocks. The bedrock is fractured, particularly near range-front faults that bound basin fill. The bedrock has hydraulic conductivity values similar to those of the basin fill in these areas. A regional flow system has been identified in the bedrock (Eakin, 1966; Dettinger, 1989).

Basin-fill deposits in the northern and western parts of Las Vegas Valley are composed primarily of carbonate clasts. These sediments are deficient in clay-sized particles relative to alluvium derived from clastic or crystalline terranes and frequently contain caliche or other carbonate cement (Plume, 1989). Basin-fill deposits are moderately thick (greater than 1,000 ft) and underlie the entire width of the broad valley floor. Depth to ground water ranges from about 20 to 650 ft. Streams lose water to evapotranspiration and aquifers.

Basin-fill deposits south of Las Vegas are composed primarily of volcanic clasts, contain significant amounts of clay derived from weathering of feldspar minerals, and are relatively unconsolidated. In this part of the basin, basin-fill deposits are typically greater

than 5,000 ft thick and occupy the wide valley floor. Depth to ground water is less than 10 ft; ground-water levels are generally constant (Wood, 1988).

Basin-fill deposits east of Las Vegas primarily consist of carbonate and gypsiferous clasts with minor volcanic and clastic material, clay minerals, and gypsum and carbonate cements. The hydraulic conductivity of basin fill is high on the north and west sides of the valley and low to the south and east of Las Vegas.

Carson River Basin

The Carson River Basin includes approximately 3,970 mi² in western Nevada (pl. 2). Altitudes are greatest in the Sierra Nevada, as much as 10,900 ft in the west where the climate is classified as humid continental, and average annual precipitation exceeds 30 in. (Covay and others, 1996). Mountain ranges throughout the central and eastern parts of the basin are lower than 8,900 ft in altitude and have subhumid continental climates. Valleys have mid-latitude steppe climates except Carson Desert where the altitude is as low as about 3,900 ft. Carson Desert is a mid-latitude desert and has an average annual precipitation of less than 5 in.

The Alpine Decree, issued in 1980, established respective Carson River surface-water rights and reservoir storage rights in high alpine reservoirs for parties in California and Nevada (California Department of Water Resources, 1991a). The larger lakes and reservoirs in the Carson River Basin are shown on plate 2. Several high alpine reservoirs are in the headwater area of the Carson River. The reservoirs are small, with storage capacities ranging from 31 to 2,948 acre-ft (California Department of Water Resources, 1991a). They are used by private parties and ditch companies to augment summer flow in the Carson River for downstream agricultural purposes in Carson and Dayton Valleys, including irrigation of alfalfa and pasture, and livestock watering.

Lahontan Reservoir (pl. 2), the only large storage reservoir in the Carson River Basin, is about 18 mi west of Fallon on the Carson River with a drainage area of about 1,800 mi² (Garcia and others, 1992). The reservoir is impounded by an earth- and gravel-filled dam and has a usable storage capacity of about 295,000 acre-ft (California Department of Water Resources, 1991a). At the spillway, the surface area is about 21 mi² (Garcia and others, 1992). Water is supplied to this reservoir by the Carson River and the Truckee River

through the Truckee Canal. The reservoir supplies approximately 87,500 acre-ft of water annually for irrigation in the Newlands Project (California Department of Water Resources, 1991b). A small 1.92 megawatt hydropower plant supplies power to the immediate vicinity. Most excess water and irrigation return flows terminate in the Stillwater Marsh area of the Carson Sink. Water from Lahontan Reservoir is a calcium sodium bicarbonate type with concentrations of dissolved solids generally less than 300 mg/L (Cooper and others, 1983; Cooper and others, 1985). The pH ranges from 6.5 to 7.5 in the winter and is uniform with depth, but can exceed 8.5 at the surface during summer. Mercury from historical silver and gold milling in the Virginia City area has accumulated in sediments in the lake, and concentrations that exceed the recommended level for human consumption (1 µg/g wet weight) have been found in the tissue of numerous fish species (Cooper and others, 1983; Cooper and others, 1985).

The Carson River originates as two distinct forks, the East and West Forks, from high altitudes in the Sierra Nevada south of Lake Tahoe. The East and West Forks of the Carson River converge in the Carson Valley and form the main stem of the Carson River.

The Carson River flows approximately 180 mi from the headwater of the East Fork to the terminus in Carson Desert. The Carson River flows through five hydrographic areas; in downstream order, these are the Carson Valley, Eagle Valley, Dayton Valley, Churchill Valley, and Carson Desert Hydrographic Areas (Rush, 1968). The East Fork and the West Fork of the Carson River are unregulated except for small irrigation impoundments. The average streamflow for the East Fork near Markleeville (site 24, pl. 2 and app. A) was about 352 ft³/s for water years 1970-90 (Covay and others, 1996). The average streamflow for the West Fork at Woodfords (site 31), which drains an area about one-quarter the size of the East Fork drainage area, was 105 ft³/s. The average streamflow for the Carson River near Carson City (site 39), at the north end of Carson Valley, was about 413 ft³/s for water years 1970-90. The average streamflow at the downstream boundary of Dayton Valley near Fort Churchill (site 46) was about 386 ft³/s. During occasional drought periods, the river was dry at this site. Water in the Truckee Canal contributed an average of about 210 ft³/s to Lahontan Reservoir on the lower Carson River. The average discharge below Lahontan Reservoir (site 48), at the upstream boundary of Carson Desert, was about

532 ft³/s. Downstream from Lahontan Reservoir, the Carson River flows into Carson Desert and streamflow diminishes rapidly owing to irrigation diversions.

Most of the aquifer recharge in the Carson River Basin is from snowmelt in the higher altitudes of the Sierra Nevada and Pine Nut Mountains. The mountains are composed of mafic and felsic flows and felsic intrusions with generally low hydraulic conductivity. Zones of higher hydraulic conductivity are found in fractured zones associated with faulting and frequently are the conduits by which recharge from the mountain blocks flows to basin-fill aquifers. An area has been identified by Maurer (1986) on the west side of Carson Valley where fractured bedrock lies at shallow depths beneath basin fill, upward gradients are present, and water levels in wells recover rapidly from seasonally high evapotranspiration.

In Carson, Eagle, Dayton, and Churchill Valleys and Carson Desert, basin-fill deposits typically are thick (greater than 1,000 ft thick), underlie the entire width of valley floors, and have hydraulic conductivities ranging from 10 to 100 ft/d (Maurer and others, 1996). Ground-water levels fluctuate as much as 10 ft as a result of irrigation. Depth to ground water ranges from about 0 to 50 ft in Carson and Eagle Valleys, and from about 10 to 100 ft in the other valleys. The basin-fill aquifer in Carson Valley generally gains water from streams that flow from the range front, and it loses water by evapotranspiration and by discharge to the Carson River. The basin-fill aquifer in the Carson Desert generally gains water only from the Carson River and irrigation canals, and nearly all the inflow is lost to evapotranspiration. A local basalt aquifer near Fallon is surrounded by basin fill and is used extensively for public supply (Glancy, 1986).

Truckee River Basin

The Truckee River Basin is adjacent to the Carson River Basin and encompasses about 3,230 mi² (pl. 2) and the hydrologic setting is similar to that of the Carson River Basin. Precipitation is greatest in the Sierra Nevada, where it exceeds 30 in/yr and the climate is classified as humid continental. Mountain ranges throughout the central and eastern parts of the basin have subhumid continental climates. The valleys have mid-latitude steppe climates. In terminal parts of the basin, average annual precipitation is less than 5 in. (Covay and others, 1996).

The Truckee River Agreement, promulgated in 1935, is the current legal basis for the operation of the Truckee River, including the tributaries and diversions from its source at Lake Tahoe to its terminus at Pyramid Lake. Upstream reservoirs are operated under supervision of the Federal Water Master, who administers requirements of the Orr Ditch Decree to achieve mandated streamflow rates (Floriston Rates) at the California-Nevada border. The Orr Ditch Decree, promulgated in 1944, incorporates the Truckee River Agreement and affirms individual municipal, industrial, and agricultural water rights. The Truckee-Carson-Pyramid Lake Water Rights Settlement Act, Public Law 101-618, was passed in 1990. This law provides a foundation for developing operating criteria for interstate allocation of water for irrigation, public supplies, fish and wildlife, and recreational uses, and to meet water-quality standards (Bohman and others, 1995).

The Truckee River flows approximately 120 mi from its headwaters in Lake Tahoe to its terminus at Pyramid Lake (pl. 2). The streamflow is regulated by six impoundments—Donner Lake, Martis Creek Reservoir, Prosser Creek Reservoir, Independence Lake, Stampede Reservoir, and Boca Reservoir—on tributary streams and a 6.1-ft-high dam on Lake Tahoe at its spillway to the Truckee River. These lakes and reservoirs were impounded for irrigation, public supply, flood control, fishery enhancement, hydropower, and recreation (California Department of Water Resources, 1991b). Donner Lake has a storage capacity of about 9,500 acre-ft; the water is used for public supply in Reno and Sparks, and for irrigation in the Newlands Project. Independence Lake has a usable storage of 17,500 acre-ft that is used for public supply in Reno and Sparks. Martis Creek Reservoir provides 20,400 acre-ft of temporary storage for flood control. Prosser Creek Reservoir impounds up to 29,800 acre-ft for flood control; water can be released for irrigation in the Newlands Project when traded for Lake Tahoe water, allowing more water to remain in Lake Tahoe during the summer. Stampede Reservoir can impound up to 226,500 acre-ft of water; the water is released primarily to provide fishery flows for Pyramid Lake. Incidental uses include recreation, flood control, and power generation. Boca Reservoir impounds up to 41,100 acre-ft of water; water is used for Truckee Meadows irrigation and public supplies for Reno and Sparks. A large proportion of flow is diverted by Derby Dam from the lower Truckee River to the Carson River through the Truckee Canal. Prior to the construction of Derby Dam,

flow from the Truckee River sometimes entered Winnemucca Lake Basin, but the lake has been dry for many years and flow now terminates at Pyramid Lake.

The Truckee River originates in the Lake Tahoe Basin Hydrographic Area and then flows through five hydrographic areas along its reach—Truckee Canyon, Truckee Meadows, Tracy Segment, Dodge Flat, and Pyramid Lake Hydrographic Areas (Rush, 1968). Three hydrographic areas north of the main valley—Spanish Springs, Sun, and Warm Springs Valleys—contribute little surface-water flow to the Truckee River. Two hydrographic areas to the south—Pleasant and Washoe Valleys—contribute intermittent runoff to the river by way of Steamboat Creek. A small subbasin (about 105 mi²), the Fernley Hydrographic Area, also is included in the study area because the Truckee Canal passes through it.

Streamflow in the Truckee River at Farad (site 138, pl. 2 and app. A), below all regulating impoundments in the Sierra Nevada, was about 851 ft³/s for water years 1970-90 (Covay and others, 1996). Part of the Truckee River flow is diverted for irrigation and public supplies as it enters Truckee Meadows. Flow in the river declined in the Reno-Sparks area (near site 149) to an average of about 748 ft³/s during water years 1970-90. Irrigation returns and treated sewage effluent from the Reno-Sparks treatment plant flow into the river at Steamboat Creek, downstream from Sparks. At Vista (site 156), near the downstream margin of Truckee Meadows, flow averaged about 883 ft³/s for water years 1970-90.

Downstream from Vista, the Truckee River flows through the Tracy Segment Hydrographic Area, a narrow canyon with small, intermittent tributaries. Some local diversions for irrigated agriculture are along this reach, and the Truckee Canal diverts water from Derby Dam to Lahontan Reservoir in the Carson River Basin. The average flow in the Truckee River below Derby Dam (site 162) was about 562 ft³/s for water years 1970-90.

Few intermittent streams contribute water downstream from Derby Dam, and small local diversions remove water for irrigated agriculture. Average flow in the Truckee River near Nixon (site 171) was about 614 ft³/s for water years 1970-90 (Covay and others, 1996). Nowlin (1987a) estimated that approximately 24 ft³/s of ground water was discharged to the Truckee River between the Derby Dam and Nixon sites. He also pointed out that even good streamflow records are accurate to only ± 10 percent; the difference in average flow between two sites during water years 1970-90 is

only 9.2 percent. The water level in Pyramid Lake has declined about 65 ft during 1906-92, mostly because of diversions to Lahontan Reservoir on the lower Carson River through the Truckee Canal. Annual evaporation from Pyramid Lake exceeds the average inflow of the Truckee River.

Most aquifer recharge in the Truckee River Basin is from snowmelt in the Sierra Nevada, Virginia Range, and Pah Rah Range. In mountainous areas, basin-fill deposits are typically thin, occupy narrow valley floors, and are highly transmissive. In the southern part of Lake Tahoe Basin, a principal unconsolidated aquifer is present (Covay and others, 1996). Most streams gain flow from surface runoff and shallow ground-water discharge throughout the year.

In the Truckee Meadows, basin-fill deposits are typically thicker than 3,900 ft, underlie the entire width of the broad flat valley floor, and have hydraulic conductivities ranging from 1 to 100 ft/d (Van Denburgh and others, 1973). Depth to ground water ranges from about 2 to 230 ft, and tributary streams lose flow to evapotranspiration and to the basin-fill aquifer. The basin-fill aquifer discharges to the Truckee River and to numerous wells for public and domestic supply.

In the lower basin—including downstream parts of the Tracy Segment, Dodge Flat, Pyramid, and Winnemucca Lake Valley Hydrographic Areas (Rush, 1968)—basin-fill deposits are typically thicker than 500 ft, occupy the wide valley shoulders, and underlie the lakes; hydraulic conductivity values range from 1 to 100 ft/d. Depth to ground water ranges from 30 to 100 ft, and ground-water levels fluctuate as much as 3 ft annually because of seasonal irrigation practices. Water levels in basin-fill deposits have dropped concomitantly with declines in the level of Pyramid Lake.

Population, Land Use, and Water Use

The population of the study unit in 1990 was 1,090,000 (Nevada State Demographer, Bureau of Business and Economic Research, written commun., 1991). Nevada had the Nation's greatest population growth rate by percentage and was fourth in percentage of the population residing in urban areas—more than 88 percent of the population lived in towns of 2,500 or more. Most of the population in Nevada (more than 90 percent) resided in the study unit, and most of the land in the study unit was federally owned range land or forest. Water use in the study unit during 1990 was approximately 1,117,000 acre-ft (E. James Crompton, U.S. Geological Survey, written commun., 1992).

Recent changes in land and water uses within the study unit include urbanization, suburbanization, and a gradual decline in agriculture.

Las Vegas Valley Area

The Las Vegas Valley area had a population of about 710,000 in 1990 (Nevada State Demographer, Bureau of Business and Economic Research, written commun., 1991). Most of the people (about 690,000) resided in the Las Vegas urban area, the fastest growing area in the State. The principal economic activities were gaming and recreation related to tourism. Commerce, warehousing, light industry, and manufacturing also were important.

Land use in the Las Vegas Valley area was about 79 percent range, 14 percent forest, 5 percent urban, less than 1 percent open water and wetlands, and 1 percent barren (Covay and others, 1996). Lake Mead on the Colorado River was the primary source of water in the area, providing about 80 percent of the approximately 317,000 acre-ft of water used in 1990 (E. James Crompton, U.S. Geological Survey, written commun., 1991). Ground water pumped from the basin-fill deposits provided the rest. Public-supply use was about 91 percent of the total use, self-supplied commercial and domestic use was about 4 percent, self-supplied industrial and mining use was about 3 percent, and irrigation was about 2 percent. About 113,000 acre-ft of treated sewage effluent was returned from the Las Vegas area to Lake Mead (1990), and about 1,000 acre-ft of effluent was used for irrigation.

Carson River Basin

The Carson River Basin had a population of about 89,000 in 1990; most of the people lived in the Carson City area (Wayne Solley, U.S. Geological Survey, written commun., 1991). The principal economic activities were commerce, gaming, recreation related to tourism, and light industry in support of mining. Carson City, the State capital, had light industry and commerce in support of tourism and government. Ranching and irrigated agriculture were important in Carson Valley, where about 47,000 acres were irrigated, and in the Newlands Irrigation Project near Fallon, where about 68,000 acres were irrigated (California Department of Resources, 1991a).

In the upper reaches of the Carson River Basin, forest land managed by the U.S. Forest Service predominated, and cattle grazing was allowed. Alfalfa

cultivation, dairy farms, and cattle grazing dominated in Carson Valley. Land use in the Carson River Basin was about 62 percent range, 18 percent forest, 14 percent open water and wetlands, 5 percent irrigated agriculture, and 1 percent urban. About 90 percent of the 538,000 acre-ft of water used in 1990 was from surface-water sources (E. James Crompton, U.S. Geological Survey, written commun., 1991). Irrigation use was about 95 percent of the total use, and public-supply use was about 4 percent. About 7,000 acre-ft of treated sewage effluent was returned to surface-water systems in 1990; about 7,000 acre-ft was used for irrigation.

Truckee River Basin

The Truckee River Basin had a population of about 290,000 in 1990 (Wayne Solley, U.S. Geological Survey, written commun., 1991). The largest population center is the Reno-Sparks urban area (about 200,000; Nevada State Demographer, Bureau of Business and Economic Research, written commun., 1991). The principal economic activities were commerce, gaming, recreation related to tourism, warehousing and light industry.

Land use in the Truckee River Basin was about 53 percent range, 27 percent forest, 12 percent open water and wetlands, 3 percent urban, 3 percent barren, and 2 percent irrigated agriculture. Surface water was the primary water resource; about 76 percent of the 262,000 acre-ft of water used in 1990 was from surface-water sources (E. James Crompton, U.S. Geological Survey, written commun., 1991). Irrigation use was about 59 percent of the total use, and public-supply use was about 36 percent. About 43,000 acre-ft of treated sewage effluent was returned to surface-water systems in 1990, and about 5,000 acre-ft was used for irrigation.

NUTRIENT, PESTICIDE, AND SEDIMENT ISSUES

Water-quality concerns in the Nevada Basin and Range study unit result from natural and human-caused conditions. Particularly important to this study of nutrients, pesticides, and suspended sediment are activities associated with urban and agricultural land use.

Las Vegas Valley Area

Treated sewage effluent and urban runoff are the major sources of water in lower Las Vegas Wash. Water use in Las Vegas and discharge of treated sewage to lower Las Vegas Wash have increased steadily since the mid-1940's. Two tertiary sewage-treatment plants currently are in operation near the southeastern edge of Las Vegas. In 1990, effluent discharged by the treatment plants was about 86 percent of the streamflow in Las Vegas Wash.

Little irrigated agricultural land remains in Las Vegas Valley. Most was abandoned or converted to other uses prior to the introduction of organochlorine pesticides in the 1940's; some fertilizers, however, may have been used for agricultural purposes. Irrigated urban land is extensive in the Las Vegas area. Golf courses, parks, lawns, and other landscaped tracts are heavily watered; fertilizers and pesticides are frequently applied during the year-round growing season.

Erosion of Las Vegas Wash associated with increasing streamflows has destroyed a wetland along the channel and during 1969-84 enough sediment to cover 1 mi² to a depth of 4 ft was eroded from Las Vegas Wash (Glancy and Whitney, 1986). Flow in Las Vegas Wash is increasing because of rapid population growth and associated increases in sewage discharge and storm-water runoff. Changes in land cover associated with urbanization, especially increases in paved areas, could cause flood response times to decrease and flood intensity to increase, increasing channel erosion. Clearing of land and other construction activities in the rapidly urbanizing Las Vegas area have disturbed soils and exposed them to erosion.

Carson River Basin

Treated sewage effluent from South Lake Tahoe and the surrounding area is pumped into Carson Valley to limit the nutrient load to Lake Tahoe. The effluent is used to irrigate farms, parks, and golf courses; it is applied in wetlands in Carson Valley, used for dust control in construction areas, and disposed of in rapid-infiltration basins. Since 1987, all direct effluent discharges to the Carson River have been diverted to off-channel disposal (Gary Hoffman, Carson City Utility Department, oral commun., 1993). Septic fields are located throughout the basin, and are particularly common in

Carson Valley and Carson Desert. Sewage disposal can contribute nutrients and pesticides from industrial, commercial, and domestic activities to water resources.

About 47,000 acres in Carson Valley and about 68,000 acres in the Newlands Irrigation Project in Carson Desert are used for irrigated pasture and growing alfalfa (California Department of Water Resources, 1991a). Pesticides and fertilizers are used in crop production, and cultivation practices affect sediment loads in nearby drainage ditches and streams.

Landscape activities at golf courses, nurseries, parks, and private residences are common in the basin. Pesticides and fertilizers can be leached into shallow ground water by frequent irrigation, and they can enter surface water by storm runoff, runoff from irrigated landscapes, and discharge from shallow ground water. Construction activities disturb and expose soils to erosion.

Truckee River Basin

Treated effluent from communities along the north shore of Lake Tahoe is transported to a site in Truckee Canyon for land application. This effort is to help maintain the clarity of Lake Tahoe; however, contributions of nutrients and sediments to the lake by

non-point sources remains an important issue. Tertiary treated sewage from the Reno-Sparks urban area is discharged into the Truckee River by way of Steamboat Creek. Septic systems are located throughout the Truckee River Basin, and are particularly common in Truckee, the Reno-Sparks area, the Steamboat Creek drainage area, and downstream from Tracy. Leachate from septic systems has entered shallow aquifers and may enter streams in these areas.

Some irrigated agricultural land remains in the Truckee Meadows, along the Truckee River downstream from Wadsworth, and along the Truckee Canal near Fernley. Agricultural land in Truckee Meadows is rapidly being converted to urban and suburban use. Irrigated acreage in Truckee Meadows has decreased from about 38 mi² in 1969 to about 23 mi² in 1978 and is projected to be less than 4 mi² by the year 2000 (Fordham, 1982). Landscape activities are present at golf courses, nurseries, parks, and private residences throughout the Truckee River Basin. Landscape fertilizer and pesticide uses have been restricted in the Lake Tahoe Basin, but are widespread in the Truckee Meadows area. Construction activities expose soils to erosion.

NUTRIENTS IN SURFACE WATER

By Stephen J. Lawrence

INTRODUCTION

Concentrations of nitrogen and phosphorus compounds, particularly ammonia, nitrate, total phosphorus, and orthophosphate, are important indicators of water quality. Natural or background concentrations of nitrogen and phosphorus in streams generally are less than 1-2 mg/L and less than 0.1 mg/L, respectively (Mueller and Helsel, 1996). Nutrient concentrations that exceed the background levels commonly indicate that water is contaminated by human or animal waste, nitrogen or phosphorus fertilizers, or other nitrogen or phosphorus sources. Large amounts of nitrogen or phosphorus can have profound effects on rivers and streams.

Nitrogen and phosphorus are plant nutrients that stimulate the growth of algae and submerged or emergent aquatic plants. Most uncontaminated rivers and streams have dynamic equilibrium between algal and aquatic plant growth and depletion through consumption by aquatic vertebrates (fish and waterfowl) and aquatic invertebrates (insects, crayfish, and clams). When large amounts of nitrogen and phosphorus enter a stream, algal and plant growth increases. Overabundance of aquatic vegetation can lead to low dissolved oxygen concentrations during pre-dawn hours because of the dominance of respiration processes at night. Reduced dissolved oxygen concentrations can kill sensitive fish and aquatic invertebrates. Decay of dead aquatic vegetation entrapped in streambed sediments further decreases dissolved oxygen, producing noxious and undesirable odors due to the release of methane and hydrogen sulfide gases.

Purpose and Scope of This Section

The nutrient analyses in this section are limited to available data on total nitrogen, ammonia¹ as N, nitrate as N, orthophosphate as soluble reactive phosphorus

¹In most unpolluted natural waters, ammonium ions (NH_4^+) predominate over dissolved ammonia gas (NH_3). Nonetheless, the combined concentration of ammonium and ammonia is, by convention, reported as "ammonia" for USGS laboratory results.

(P), and total phosphorus as P that were collected during October 1969-April 1990. These forms of nitrogen and phosphorus are commonly associated with degradation of surface-water quality as a result of human activities (Hem, 1985, p. 36), and, therefore, they are the forms most commonly analyzed in water samples by Federal, State, and local agencies, and by wastewater treatment facilities. The ranges of concentrations and the relation to areal and temporal trends, major point sources, land uses, national averages, and Federal or State drinking-water standards are described in this section.

Previous Investigations

In the Las Vegas Valley area, surface-water quality has not been previously studied, except for water-quality data collected on Las Vegas Wash by USEPA and USGS. Therefore, reports on previous investigations for the Las Vegas area are not available.

Carson River

The water quality of the Carson River has not received the level of attention that quality of streams in the Lake Tahoe Basin and the Truckee River have received. Much of the nutrient data for the Carson River was collected by the Nevada Division of Environmental Protection, stored in the U.S. Environmental Protection Agency STORET data base, and used in developing the 208 Water-Quality Management Plans mandated by Public Law 92-500.

The hydrologic characteristics of the Carson River Basin are described by Brown and others (1986). Nutrient and suspended-sediment concentrations and loads for sites on the Carson River are detailed by Garcia and Carman (1986) for water year 1980. Trends in total-phosphorus concentrations and loads for the USGS National Stream-Quality Accounting Network (NASQAN) site Carson River near Fort Churchill, Nev. (site 46, pl. 2 and app. A) are summarized by Smith and others (1982). They indicate that flow-adjusted total-phosphorus concentrations showed no trend at the Fort Churchill site for water years 1972-79 but that total-phosphorus concentrations tended to decrease. Most other reports on water quality in the Carson River Basin present data without interpretation.

The USGS National Water Summary 1990-91 presented information on concentrations of nutrients in the Carson River near Fort Churchill (Seiler, 1993; Smith and others, 1993). No trends were observed in concentrations of nitrite plus nitrate or dissolved phosphate during 1980-89 or 1982-89, respectively. However, the median concentration of phosphorus, 0.08 mg/L as P, at this site was the highest value of the eight major rivers evaluated for Nevada (Seiler, 1993).

Truckee River

Several studies address concerns for maintaining the clarity of Lake Tahoe and concerns about increasing eutrophication. Most emphasize transport of suspended sediment and nutrient loads to Lake Tahoe by tributary streams. Sediment and nutrient loading from Glenbrook Creek were investigated by Glancy (1977). Sediment and nutrients transported in Ward and Blackwood Creeks were investigated by Leonard and others (1979). Sediment and nutrient transport in First, Second, Third, Incline, and Wood Creeks, which are affected by the Incline Village urban area, were investigated also by Glancy (1988). The efficiency of erosion-control structures in reducing sediment and nutrient transport in Edgewood Creek was evaluated by Garcia (1988).

Water-quality and biological data from sites in the Taylor Creek watershed were compiled by Templin and others (1980). Planning documents were published by the Tahoe Regional Planning Agency (1990). Proceedings from a symposium held at Lake Tahoe contain several papers about water-quality and ecosystem studies in the Lake Tahoe Basin and the central Sierra Nevada (Poppoff and others, 1990).

Several reports and papers published during the study period pertain to nutrient concentrations in the Truckee River. These publications can be grouped into three general categories—nutrient modeling, data compilation, and data interpretation. Probably the most intensive efforts involved the construction, calibration, and verification of nutrient models for the lower Truckee River (Nowlin, 1987a,b; Caupp and others, 1991; Brock and others, 1992). Some reports are data compilations (La Camera and others, 1985; Brown and others, 1986). Other reports are interpretive and assess effects of nutrient concentrations on aquatic biota or on the general ecological “health” of the Truckee River

system (McLaren, 1977; Ryder, 1979; Hoffman and Scoppettone, 1988; Galat, 1990; Hoffman, 1990; McKenna, 1990).

A computer model for the lower Truckee River (Nowlin, 1987a) indicated that total-nitrogen and total-phosphorus loads upstream from Derby Dam are controlled by loads in sewage effluent discharged to the river by the Truckee Meadows Water Reclamation Facility (TMWRF). In addition, nonpoint sources control total-nitrogen and total-phosphorus loads in the river downstream from Derby Dam. A nutrient model (Brock and others, 1992) suggests that to meet the dissolved oxygen standard of 5.0 mg/L for streams, total-nitrogen loads in the river need to be kept below 1,000 lb/day. Hoffman and Scoppettone (1988) reported that the mortality of Lahontan cutthroat trout eggs in the lower Truckee River was caused by low concentrations of dissolved oxygen within gravel.

Concentrations of nutrients in the Truckee River near Nixon were discussed in the USGS National Water Summary 1990-91 (Seiler, 1993; Smith and others, 1993). During 1980-89, no trend was observed in nitrite plus nitrate concentrations at this site. However, during 1982-89, concentrations of dissolved phosphate decreased at this site, primarily because the Truckee Meadows Water Reclamation Facility began removing phosphorus from treated effluent discharge in 1982 (Seiler, 1993).

Limitations of Data

To meet the need for nationally comparable data (with respect to sampling and analytical methods), data collected and analyzed mainly by the USGS during the study period (October 1969 through April 1990) are used in this report. However, data collected by State and local agencies are used to address local issues, particularly changes in nutrient concentrations caused by land-use changes, and to supplement USGS data. Selected long-term surface-water sites where nutrient data have been collected in the study area during the study period are listed in appendix A and shown on plates 1 and 2.

USGS techniques for collection of nutrient samples remained constant through the 1980's. However, a study of quality assurance records by Alexander and others (1993) showed a larger positive bias for total and dissolved phosphorus and ammonia and kjeldahl nitrogen analyses during the early 1980's than during later

periods for standards analyzed by the USGS National Water Quality Laboratory. Airborne ammonia contamination may be one cause; the cause of the phosphorus contamination is unknown, but generally is observed when suspended sediment concentrations exceed 50 mg/L (Dennis Helsel, U.S. Geological Survey, written commun., 1992). Improvements in analyses (decreases in bias) since the early 1980's could result in overestimates of decreasing trends in concentrations of these constituents.

Sewage-effluent samples were collected and nutrient concentrations were analyzed by the staff of individual sewage-treatment plants in their water-quality laboratories. Nutrient data from Carson City were monthly mean concentrations. The data used to compute the monthly means were not available because they were retained for only 3 years.

Methods Used to Collect, Analyze, and Interpret Nutrient Data

Three methods were used to collect the nutrient samples referred to in this report. These are depth- and width-integration of streamflow, vertical integration of streamflow, and grab samples. Samples were collected by the USGS using the equal-width increment (EWI) method, which is a depth- and width-integration method. This method involves collecting depth-integrated samples from equal-width segments of the cross section of a stream. The vertical-integration method is a simplification of the EWI in that only one vertical, depth-integrated sample is collected in the centroid of flow. Washoe County and the Truckee Meadows Wastewater Reclamation Facility have used this method on the Truckee River since about 1985. For grab samples, a bottle or bucket is dipped in the stream. State agencies, local agencies, and universities have used grab sampling to collect nutrient samples. Nitrate and orthophosphate data from grab samples are used in this report. According to Martin and others (1992), grab sampling underrepresents total-nitrogen, ammonia, total-phosphorus, and suspended-sediment concentrations.

Several procedures were used to develop the data base from USGS, STORET, and State of Nevada data. The first procedure was to aggregate the total and dissolved forms of nitrate presented in the data base. Total and dissolved forms of nitrate, nitrite plus nitrate, and nitrite in water samples are analytically equivalent

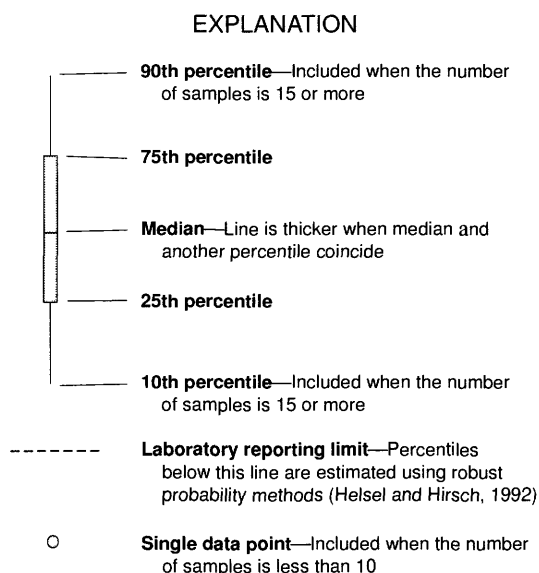
(David A. Rickert, U.S. Geological Survey, written commun., 1992). Thus, the nitrate variable was calculated as the difference between nitrate plus nitrite and nitrite concentrations—either dissolved or total, depending on which form was analyzed for in the sample. In the second procedure, total nitrogen was calculated as the sum of ammonia, organic nitrogen (kjeldahl nitrogen), and nitrite plus nitrate as nitrogen. In the third procedure, the phosphate forms of total phosphorus and orthophosphate were converted to the phosphorus form by multiplying by a conversion factor of 0.3261, the weight fraction of phosphorus in the PO_4 ion. Orthophosphate, as used in this report, is more accurately described as soluble reactive phosphorus.

Many samples contained nitrogen and phosphorus concentrations that were censored because of limitations in analytical methods and equipment. Censored data generally pose particular problems during analysis. Censored data originate from samples that do not contain measurable concentrations of a nutrient above a minimum analytical detection limit (MDL). USGS nutrient data are censored at a laboratory reporting limit, which is some value higher than an analytical detection limit. This value accounts for analytical and instrument uncertainties that can affect the precision or accuracy of the analysis. Multiple MDL's and reporting limits further complicate data analysis because a decision must be made as to which MDL or reporting limit is most appropriate for the analysis. The type of statistical method used to analyze censored data determines both the amount of information available from the data and the validity of that information. In most cases, if the correct method is not used the information is biased and does not accurately reflect the conditions in the stream or aquifer. Multiple MDL's or reporting limits are not present in the total nitrogen, ammonia, total phosphorus, or orthophosphate data bases. Two MDL's or reporting limit values (0.01 and 0.1 mg/L) are present for nitrate in the data bases used in this report. Thus, for construction of boxplots and for trend analysis, nitrate concentrations that are less than the 0.01 mg/L were estimated by probability plotting methods using nitrate concentrations greater than 0.01 mg/L (Helsel and Hirsch, 1992, p. 27, 362-363) or log normal maximum-likelihood methods were used to estimate percentiles (Helsel and Cohn, 1988).

Boxplots are used to summarize nutrient concentrations in this report.¹ The boxplots consist of a "box," whose upper limit is the population's 75th percentile value, and a lower limit, which is the 25th percentile value. A horizontal line dividing the box is the 50th percentile value (median). Extending from the top and bottom of the box are "whiskers" representing the 90th percentile value (upper whisker) and the 10th percentile value (lower whisker). Complete boxplots were constructed only if 15 or more data values were to be represented. For 10 to 14 data points, only the "box" part of the boxplot is shown (25th, 50th, and 75th percentiles) and for fewer than 10 data points, the individual points are plotted.

The statistical methods used to analyze data for this report are primarily nonparametric and include the Kruskal-Wallis analysis of variance, the Mann-Whitney t-test, the signed-ranks test (nonparametric paired t-test), and nonparametric correlation. The Mann-Whitney test is designed to test whether two groups of data are from different populations. This t-test calculates a value called the "*p*-value," which is the smallest level of significance that would allow the null hypothesis to be rejected. Nonparametric correlation was used to identify monthly trends in nutrient concentrations by constructing a variable that gives monthly variation as a sinusoidal function. This procedure provides a statistical measure of trend for data containing censored values.

¹The graphical components are as follows.



Another method used to determine trends in nutrient concentrations is Locally Weighted Scatterplot Smoothing (LOWESS) of Cleveland (1979). LOWESS is used primarily for the graphical presentation of annual and study-period trends. In this method, nutrient data are adjusted for streamflow variability by plotting concentrations against streamflow rate, smoothing the plotted data using LOWESS, and computing residuals by subtracting the values that compose the smooth line from the actual data values. The resulting residuals are added to the constituent mean, and another LOWESS is done to identify the trend within this transformed data set (Helsel and Hirsch, 1992, p. 334). If the relation between streamflow and the constituent concentration has not changed during the period analyzed by the trend test, a trend in the residuals implies a trend in concentration. Prolonged drought may alter the relation, resulting in a trend owing to natural causes. Study-period trends were evaluated by (1) assigning October 1, 1969, as day 1 and April 30, 1990, as day 8,030 in the study period, (2) plotting flow-adjusted values on the days the samples were collected, and (3) applying LOWESS to the plot. Annual trends were evaluated by (1) plotting each flow-adjusted value for samples collected during the study period as a day representing the day in a 365- or 366-day year that it was collected, and (2) applying LOWESS. The LOWESS smooth line for an annual trend generally is not a continuous line with the same value at December 30 and January 1.

Nutrient loads were calculated using regression methods, log transformation of the data, and a bias correction using the "smearing estimator" of Helsel and Hirsch (1992). Nutrient concentrations were converted to mass units by multiplying them by log-transformed instantaneous streamflow, and regressed against the log-transformed instantaneous streamflow measured when the sample was taken. Daily mean streamflow values for each day of the study period were used in the regression equation to compute daily nutrient loads (in log base-10 units), which were summed, corrected for transformation bias, and converted to original units. Daily loads were summed to compute monthly and annual nutrient loads. Bar charts show the monthly and annual nutrient loads for the study period.

Cumulative percentiles of daily mean streamflow were calculated using data from USGS streamflow-gaging stations. Nutrient concentrations were associated with a cumulative streamflow percentile by the instantaneous discharge measured at the time of sample

collection. Nutrient concentrations were plotted against cumulative percentiles of daily mean flow using LOWESS to compare the response of nutrient concentrations to streamflow at different sites. The cumulative percentiles normalize streamflow regimes and allow comparisons of nutrient behavior for different sites.

Atmospheric Deposition

The National Atmospheric Deposition Program (NADP; Bigelow and Dossett, 1988) began in 1978 to provide a formal basis for research into the problem of acidic deposition (acid rain) and to develop a nationwide precipitation-monitoring network. Under the auspices of NADP (Bigelow and Dossett, 1988), wet-deposition samples are collected at 200 sites in rural areas of the United States as part of a National Trends Network (NTN). These samples are analyzed for calcium, magnesium, sodium, potassium, chloride, sulfate, bicarbonate, nitrate, ammonia, orthophosphate, pH, and specific conductance. Precipitation volumes are recorded also.

The primary objectives of the NADP-NTN program are to determine spatial patterns and temporal trends in the chemical composition of precipitation and to determine the effects of that precipitation on aquatic and terrestrial ecosystems. Four NTN sites operate in Nevada—Saval Ranch in northern Nevada, Great Basin National Park in eastern Nevada, Smith Valley in western Nevada, and Red Rock Canyon in southern Nevada. The Smith Valley and Red Rock Canyon sites are closest to the NVBR NAWQA study unit; the Smith Valley site is about 40 mi southeast of the Carson River Basin and about 70 mi southeast of the Truckee River Basin and the Red Rock Canyon site is about 25 mi northwest of Las Vegas Valley. Because these NTN sites are outside the basins addressed in this report and only 5 years of record are available, the nutrient data in precipitation collected at these sites were not interpreted. A summary of ammonia and nitrate concentrations measured at both sites is in table 1.

NUTRIENT CONCENTRATIONS AND LOADS IN THE LAS VEGAS VALLEY AREA

The Las Vegas Valley area (pl. 1) within Clark County in southern Nevada includes the largest urban area in Nevada—the Las Vegas metropolitan area. The main surface-water features are Las Vegas Wash

and Lake Mead. Two principal sewage-treatment facilities operate in Las Vegas Valley—the Clark County Sanitation District and the City of Las Vegas Water Pollution Control Facility. Both facilities discharge treated sewage effluent to Las Vegas Wash. The combined effluent discharge in 1990 was about 86 percent of the streamflow in Las Vegas Wash.

The USGS streamflow-gaging station on Las Vegas Wash near Henderson (site 13, pl. 1 and app. A) was the only site in the Las Vegas Valley area from which samples were evaluated for this study. This site is about 4 mi downstream from the sewage-effluent discharge points. Since about 1989, water-quality sampling has increased in the washes draining Las Vegas Valley. An areal description of nutrient concentrations in the washes of Las Vegas Valley was not possible because water-quality was not monitored during the study period.

Temporal Trends in Nutrient Concentrations

The discussion that follows summarizes the temporal characteristics of nutrient concentrations at Las Vegas Wash near Henderson from water year 1973 through April 1990. Of particular interest are median concentrations, the variability associated with those concentrations, and changes in nutrient concentrations during the study period and in the course of a year. Because of the artificial flow regime of Las Vegas Wash, the LOWESS procedure of graphically representing trends was not used. The rate of flow in Las Vegas Wash has increased from about 42 ft³/s in water year 1970, to 81 ft³/s in 1980, and to 170 ft³/s in 1990. This increasing rate of flow from treated sewage effluent is different from natural streamflow variability in that concentrations of dissolved and total constituents are not related to flow.

Ninety percent of total-nitrogen concentrations measured in Las Vegas Wash near Henderson were less than 20 mg/L (table 2); the median concentration was 16 mg/L. Ammonia is the principal component of the total-nitrogen concentration. Ninety percent of the ammonia concentrations were less than or equal to 16 mg/L as N. The median concentration was 12 mg/L as N (table 2). Ninety percent of nitrate concentrations were less than 4.0 mg/L as N; the median concentration was 1.1 mg/L (table 2).

Yearly concentrations of total nitrogen are directly related to ammonia concentrations (fig. 1). Yearly concentrations of nitrate are inversely related to ammonia concentrations (fig. 1). Although monthly

Table 1. Statistical summaries of precipitation-weighted mean concentrations of ammonia and nitrate in atmospheric deposition at the Red Rock Canyon and Smith Valley, Nev., sites of the National Atmospheric Deposition Program/National Trends Network¹

[Values in milligrams per liter. --, no percentile values shown when number of values is less than 10]

Site name	Year	Number of values	Minimum	Maximum	Percentile		
					25th	50th (median)	75th
Ammonia as nitrogen							
Red Rock Canyon, Clark County, Nev.	1985	11	0.03	1.49	0.33	0.47	0.85
	1986	11	.04	.43	.10	.24	.28
	1987	10	.03	.98	.11	.19	.43
	1988	10	.11	.77	.15	.18	.33
	1989	5	.02	1.60	--	--	--
	1990	11	.14	1.64	.33	.57	.84
Smith Valley, Lyon County, Nev.	1985	4	.01	.30	--	--	--
	1986	10	.01	.64	.03	.22	.35
	1987	10	.08	1.11	.09	.14	.33
	1988	11	.01	1.00	.13	.15	.40
	1989	12	.01	.97	.09	.26	.61
	1990	10	.10	1.14	.20	.31	.69
Nitrate as nitrogen							
Red Rock Canyon, Clark County, Nev.	1985	11	.21	11.63	1.89	3.72	8.51
	1986	11	.51	3.10	.81	1.37	2.14
	1987	10	.66	6.14	.91	1.36	2.60
	1988	10	.22	3.08	.60	1.32	2.51
	1989	5	.33	3.81	--	--	--
	1990	11	.85	4.48	1.00	1.92	4.20
Smith Valley, Lyon County, Nev.	1985	4	.02	.46	--	--	--
	1986	10	.03	11.05	.12	.87	1.31
	1987	10	.18	5.46	.24	.39	2.97
	1988	11	.01	3.31	.35	.73	1.72
	1989	12	.07	3.12	.25	.75	1.01
	1990	10	.31	3.15	.47	.70	1.41

¹ Samples from Red Rock Canyon site were collected by Bureau of Land Management personnel; samples from Smith Valley site were collected by U.S. Geological Survey personnel. All samples were analyzed by Central Analytical Laboratory, Illinois State Water Survey, Champaign.

Table 2. Statistical summaries of nitrogen and phosphorus in water samples from Las Vegas Wash near Henderson, Nev. (site 13, pl. 1), water year 1973 through April 1990

[Values in milligrams per liter.]

Constituent	Number of samples in relation to reporting limit		Minimum ¹	Maximum	Percentiles				
	Above	Below			10th	25th	50th (median)	75th	90th
Total nitrogen	142	0	5.5	26	12	14	16	18	20
Ammonia as nitrogen	194	0	.01	21	7.2	9.2	12	14	16
Nitrate as nitrogen	184	14	<.01	12	.05	.42	1.1	2.0	4.0
Total phosphorus	195	1	<.01	8.5	.53	.70	1.0	5.1	6.5
Orthophosphate as phosphorus	62	0	.09	.60	.20	.30	.40	.50	3.6

¹ Laboratory reporting limits are indicated by the "<" symbol.

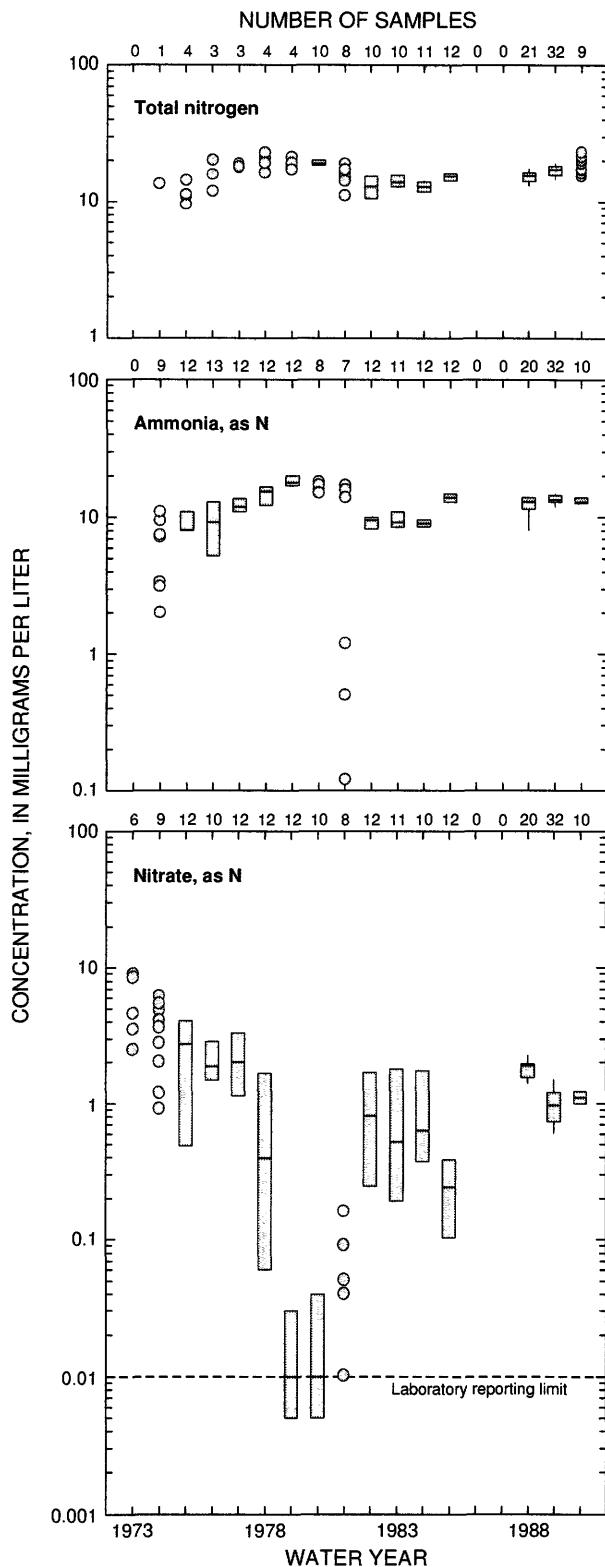


Figure 1. Yearly concentrations of total nitrogen, ammonia, and nitrate for Las Vegas Wash near Henderson, Nev., water year 1973 through April 1990.

concentrations of total nitrogen show little variation, median concentrations of ammonia were higher in late spring and early summer and median concentrations of nitrate were lowest in mid to late summer (fig. 2).

Samples were collected in Las Vegas Wash near Henderson and measured for total-phosphorus concentrations beginning in water year 1974 and continuing

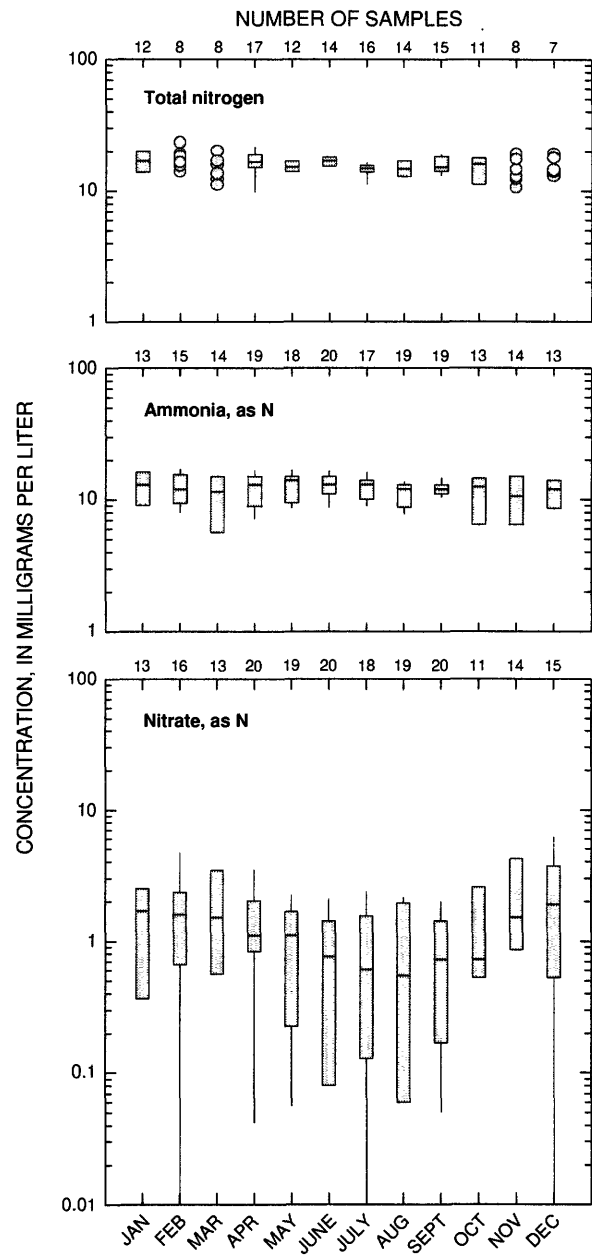


Figure 2. Monthly concentrations of total nitrogen, ammonia, and nitrate for Las Vegas Wash near Henderson, Nev., water year 1973 through April 1990.

through April 1990 (fig. 3). Ninety percent of the total-phosphorus concentrations were less than 6.5 mg/L; the median concentration was 1.0 mg/L (table 2).

Boxplots of yearly total-phosphorus concentrations during the study period show a sharp decrease in concentration after 1981 (fig. 3). This decrease is highly significant (p less than 0.001 using the Mann-Whitney U-test, a nonparametric t-test). The removal of phosphorus from sewage effluent discharged to the wash began in 1981 (Hess and others, 1993, p. 89). Median concentrations of total phosphorus were lower during the spring and summer, probably because of uptake by algae and aquatic macrophytes (fig. 4).

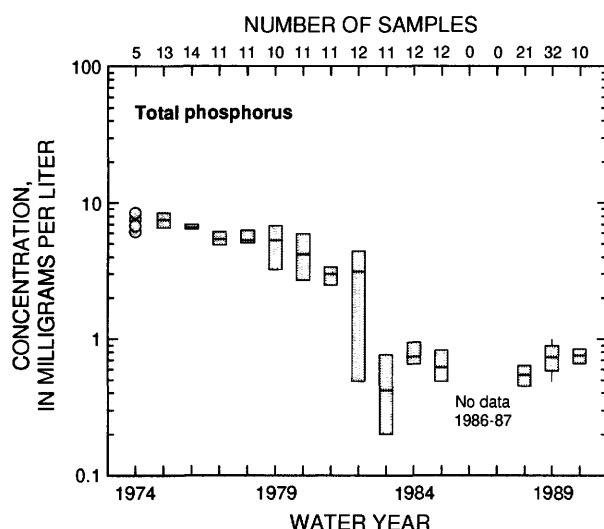


Figure 3. Yearly concentrations of total phosphorus for Las Vegas Wash near Henderson, Nev., water year 1974 through April 1990.

Data are not sufficient for an evaluation of orthophosphate because orthophosphate measurements in samples began in 1988. Ninety percent of orthophosphate concentrations were less than or equal to 3.6 mg/L as P; the median concentration was 0.40 mg/L (table 2).

Nutrient Loads

Nutrient loads were calculated using the regression method described in the introduction to this section. Equations used for computing nutrient loads are in table 3. The total-nitrogen load for Las Vegas Wash increased from about 750 tons in water year 1974 to about 2,400 tons in water year 1988. The increase in nitrogen load was caused by an increase in sewage

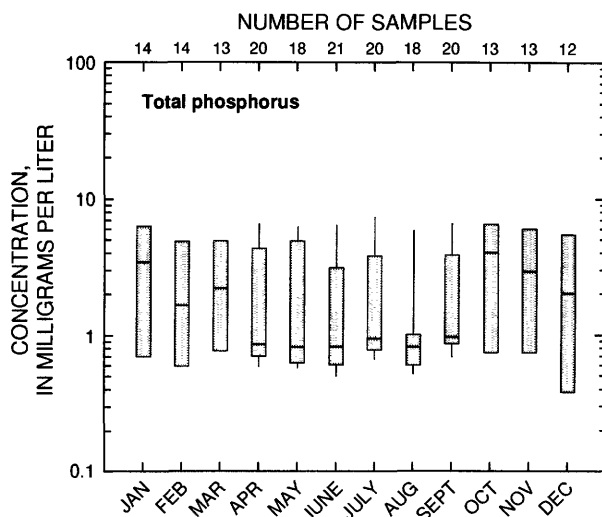


Figure 4. Monthly concentrations of total phosphorus for Las Vegas Wash near Henderson, Nev., water year 1974 through April 1990.

effluent discharged to the wash as the population in Las Vegas Valley increased during the study period. Mean monthly total-nitrogen loads were lowest in the spring and summer, possibly because of uptake by algae and aquatic macrophytes (fig. 5).

Total-phosphorus loads were not computed. Regression equations developed for the pre- and post-treatment periods for phosphorus explained less than 50 percent of the variation in load.

NUTRIENT CONCENTRATIONS AND LOADS IN THE CARSON RIVER BASIN

Beginning in 1987, all direct effluent discharges to the Carson River were diverted to off-channel disposal (Gary Hoffman, Carson City Utility Department, oral commun., 1993). Currently (1993), all effluent is disposed of by land-surface applications to agricultural fields or wetlands and by land-surface application after reservoir storage.

The most complete data were from USGS stream-flow-gaging stations, particularly the Carson River near Fort Churchill (site 46, pl. 2 and app. A). This site was part of the USGS National Stream-Quality Accounting Network (NASQAN). Supplementary nitrate and orthophosphate data from other agencies were used.

Table 3. Regression models used to compute loads of total nitrogen and total phosphorus in streams of the Nevada Basin and Range NAWQA study unit, water year 1970 through April 1990

[Form of regression model: $\log\text{load} = a + b\log Q + c(\log Q)^2 + d\sqrt{Q} + eQ^2 + fT + gJULIAN + h\log JULIAN^2 + j\sin(2\pi T) + k\cos(2\pi T)$; the antilog of $\log\text{load}$ ($10^{\log\text{load}}$) is in tons per day. Abbreviations: log, logarithm base-10; Q, streamflow in cubic feet per second; sqrt, square root; T, calendar year + (JULIAN/number of days in year) - 1900; JULIAN, cumulative day in a year (1-365 or 366); --, coefficient was not used in model; r^2 , coefficient of determination, the amount of variance in $\log\text{load}$ accounted for by independent variables; CV, coefficient of variation of \log form of regression, computed by dividing root mean square error by mean of load values, in log units; bc, smearing estimate used to correct for bias incurred during log transformation, is multiplied by antilog of load computed from regression model in base-10 units to develop final load estimate]

Nutrient	Constants in equation											Regression statistics		
	a	b	c	d	e	f	g	h	i	j	k	r^2	CV	bc
Nitrogen	-1.82	0.988	--	--	--	--	--	--	--	--	--	0.81	14	1.02
Las Vegas Wash near Henderson, Nev. (site 13, pl. 1)														
Nitrogen	-2.61	1.07	--	--	--	--	--	-0.130	--	--	0.009	.97	-27	1.12
Carson River near Fort Churchill, Nev. (site 46, pl. 2)														
Phosphorus	-2.26	1.02	--	--	0.030	-0.015	--	--	--	--	.052	.99	-12	1.06
Third Creek near Crystal Bay, Nev. (site 93, pl. 2)														
Nitrogen	-3.31	1.18	--	--	--	--	0.001	--	--	0.341	--	.91	-17	1.41
Phosphorus	-4.46	1.34	0.214	--	--	--	--	--	-4.96x10 ⁻⁷	--	-.037	.79	-14	2.00
Incline Creek near Crystal Bay, Nev. (site 96, pl. 2)														
Nitrogen	-.632	--	.627	--	--	-.025	--	--	--	.003	--	.70	-18	1.34
Phosphorus	-4.73	.802	--	0.396	--	--	--	--	--	--	.087	.83	-12	1.50
Truckee River near Nixon, Nev. (site 171, pl. 2)														
Nitrogen	-2.54	1.12	--	--	--	--	--	-.165	--	--	--	.94	-23	1.12
Phosphorus	1.11	1.03	--	--	.006	-.056	-.004	--	--	--	-.024	.93	-24	1.21

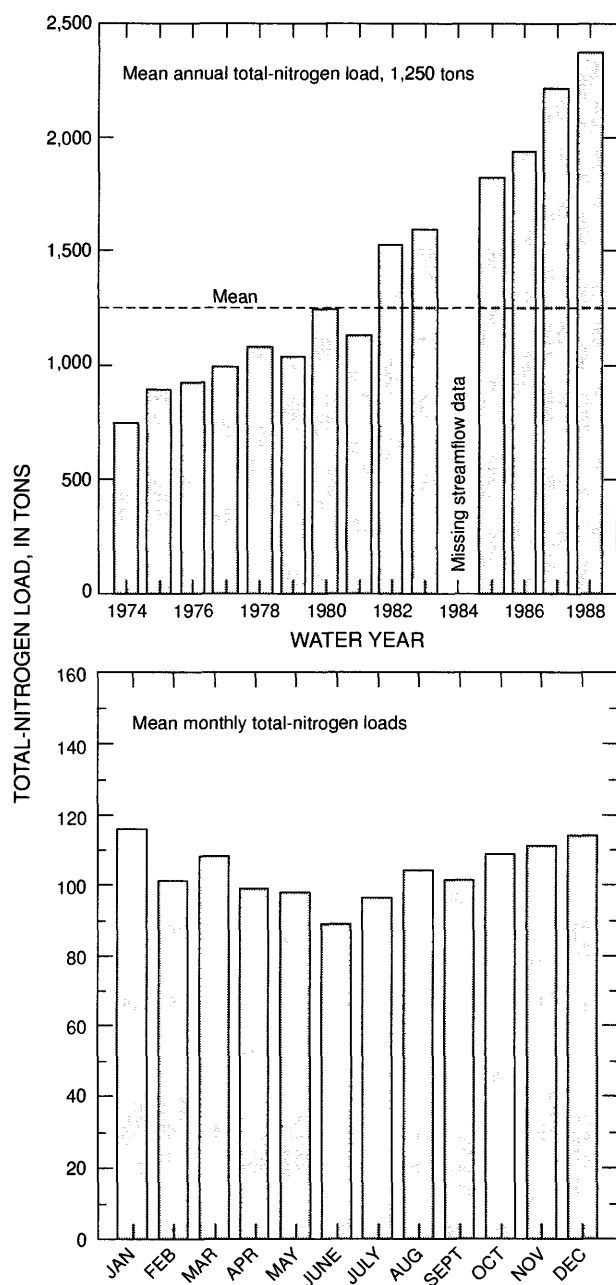


Figure 5. Yearly and mean monthly total-nitrogen loads for Las Vegas Wash near Henderson, Nev., water years 1974-88.

Areal Distribution of Nutrient Concentrations

This section of the report provides an assessment of areal patterns in the distribution of nutrients throughout a basin. Of particular interest are the changes or patterns in nutrient concentrations as streams flow through different land-use areas. In addition, with adequate samples, the variability of nutrient concentrations along a stream gradient or

profile, beginning in the headwater areas and ending at some point downstream, can be depicted. Unfortunately, the limited number of comparable samples collected at sites on the Carson River, coupled with treated sewage-effluent discharges at several places along the length of the river during the study period, prevented such an analysis. The influence of treated sewage effluent makes it difficult to determine the effects of land use on nutrient concentrations because the land-use effects are masked by the high nutrient concentrations in sewage effluent. Also, the absence of comparable data for sites draining different land-use areas in the basin makes comparisons among sites impossible. Data are not comparable because samples were collected by different agencies using different sampling and preservation methods, and were analyzed by different laboratories.

Selected surface-water sites in the Carson River Basin where nutrient samples were collected in multiple years are shown on plate 2 and listed in appendix A. Table 4 summarizes the distribution of nutrient concentrations at those sites in the Carson River Basin that are evaluated in this report. Only a limited amount of nutrient data were available for the Gardnerville site on the East Fork Carson River (site 25, pl. 2 and app. A) and the West Fork Carson River at Woodfords, Calif. (site 31). Therefore, nitrate and orthophosphate data from the West Fork Carson River at Paynesville, Calif. (site 32), were used to characterize trends in nutrient concentrations in the forested headwaters of the Carson River Basin; nutrient data from the Carson River near Fort Churchill, Nev., were used to characterize nutrient concentrations near the distal end of the Carson River Basin. Only nitrate and orthophosphate were considered at the Paynesville site because grab sampling was used to collect samples. Non-depth-integrated samples (grab samples) tend to underrepresent total-nitrogen, ammonia, and total-phosphorus concentrations (Martin and others, 1992) and are not comparable with data from depth-integrated sampling.

The median concentration of total nitrogen at the Fort Churchill site was 0.77 mg/L (table 4). The median ammonia concentrations were the same (0.03 mg/L as N) at the Gardnerville, Woodfords, and Fort Churchill sites; the highest concentration (0.61 mg/L as N) was measured in a sample from the Fort Churchill site. Ammonia concentrations for the upper 25 percent of the values at the Fort Churchill site were nearly two times greater than at the other two sites. Nitrate concentrations were similar at the Gardnerville and Woodfords sites (table 4). All samples from the

Table 4. Statistical summaries of nitrogen and phosphorus in water samples collected at four sites on the Carson River, water year 1970 through April 1990

[Values in milligrams per liter. For percentile calculations, sample concentrations below laboratory reporting limits are estimated using robust probability methods (Helsel and Hirsch, 1992). Symbol: --, not applicable because of insufficient data for calculation]

Site number (pl. 2)	Site name	Number of samples in relation to reporting limit		Minimum ¹	Maximum	Percentile ²				
		Above	Below			10th	25th	50th (median)	75th	90th
Total nitrogen										
25	East Fork Carson River near Gardnerville, Nev.	5	0	0.24	2.8	--	--	--	--	--
31	West Fork Carson River at Woodfords, Calif.	5	0	.36	1.8	--	--	--	--	--
46	Carson River near Fort Churchill, Nev.	138	1	<.10	2.2	0.32	0.50	0.77	1.1	1.6
Ammonia as nitrogen										
25	East Fork Carson River near Gardnerville, Nev.	16	4	<.01	.07	<.01	.02	.03	.06	.07
31	West Fork Carson River at Woodfords, Calif.	11	10	<.01	.06	<.01	.01	.03	.04	.06
46	Carson River near Fort Churchill, Nev.	120	26	<.01	.61	<.01	.01	.03	.09	.14
Nitrate as nitrogen										
25	East Fork Carson River near Gardnerville, Nev.	0	17	<.10	<.10	<.10	<.10	<.10	<.10	<.10
31	West Fork Carson River at Woodfords, Calif.	0	18	<.10	<.10	<.10	<.10	<.10	<.10	<.10
32	West Fork Carson River at Paynesville, Calif.	156	66	<.01	.60	<.01	.01	.04	.09	.14
46	Carson River near Fort Churchill, Nev.	325	1	<.01	.92	<.02	.04	.10	.29	.46
Total phosphorus										
25	East Fork Carson River near Gardnerville, Nev.	20	0	.01	1.4	.02	.03	.05	.20	.25
31	West Fork Carson River at Woodfords, Calif.	18	0	.01	.23	.01	.02	.03	.05	.09
46	Carson River near Fort Churchill, Nev.	143	0	.07	.67	.11	.17	.24	.34	.40
Orthophosphate as phosphorus										
25	East Fork Carson River near Gardnerville, Nev.	14	6	<.01	.05	<.01	.02	.03	.03	.05
31	West Fork Carson River at Woodfords, Calif.	13	5	<.01	.06	<.01	.01	.02	.03	.05
32	West Fork Carson River at Paynesville, Calif.	207	13	<.01	.15	.01	.01	.01	.02	.03
46	Carson River near Fort Churchill, Nev.	237	0	.02	2.7	.06	.08	.13	.18	.22

¹ USGS Laboratory reporting limits are indicated by the "less than" symbol "<".

² Percentiles were not calculated for total nitrogen, ammonia as nitrogen, and total phosphorus at West Fork Carson River near Paynesville, Calif., site because samples were not collected by depth-integrated methods and so are not thought to be comparable with samples that were collected by that method (Martin and others, 1992).

Gardnerville and Woodfords sites had less than 0.10 mg/L of nitrate as N. At the Paynesville site the median nitrate concentration was 0.04 mg/L as N. The median nitrate concentration in samples from the Fort Churchill site was 0.10 mg/L as N. The samples from the Fort Churchill site indicate nitrogen enrichment, possibly from urban and agricultural activities. Treated sewage effluent was discharged to the river at several points upstream from the Fort Churchill site prior to September 1987 and is currently (1993) applied to land upstream.

Median total-phosphorus concentrations were 0.05 mg/L at the Gardnerville site and 0.03 mg/L at the Woodfords site (table 4). The median total-phosphorus concentration at the Fort Churchill site (0.24 mg/L) was about five to eight times higher during the study period than concentrations at the two headwater sites (table 4).

Median orthophosphate concentrations were low at Gardnerville, Woodfords, and Paynesville sites (0.03, 0.02, and 0.01 mg/L as P, respectively) in the headwater areas of the Carson River. The median orthophosphate concentration at Fort Churchill (0.13 mg/L as P) was about 4 to 10 times higher than concentrations at the three headwater sites (table 4).

Temporal Analysis of Nutrient Concentrations

This section discusses the changes in nutrient concentrations during the study period and the annual changes at a headwater site (West Fork Carson River at Paynesville, site 32) and a downstream site (Carson River near Fort Churchill, site 46). The number of samples collected at the Fort Churchill site differed from year to year, but the number of samples collected at the Paynesville site was consistent during the study period. At Fort Churchill, the most intense period of nutrient sampling was during water years 1976-81. During that time, samples were collected every 2 to 4 weeks.

Study-Period Trends

At the Fort Churchill site, total-nitrogen concentrations span a narrow range of values for all years during the study period (fig. 6); total-nitrogen concentrations at the Fort Churchill site were seldom less than 0.32 mg/L (10th percentile) or greater than 1.6 mg/L (90th percentile; table 4). Flow-adjusted total-nitrogen concentrations at the Fort Churchill site showed no trend during the 20-year study period (fig. 6). Ammonia concentrations at the Fort Churchill site generally

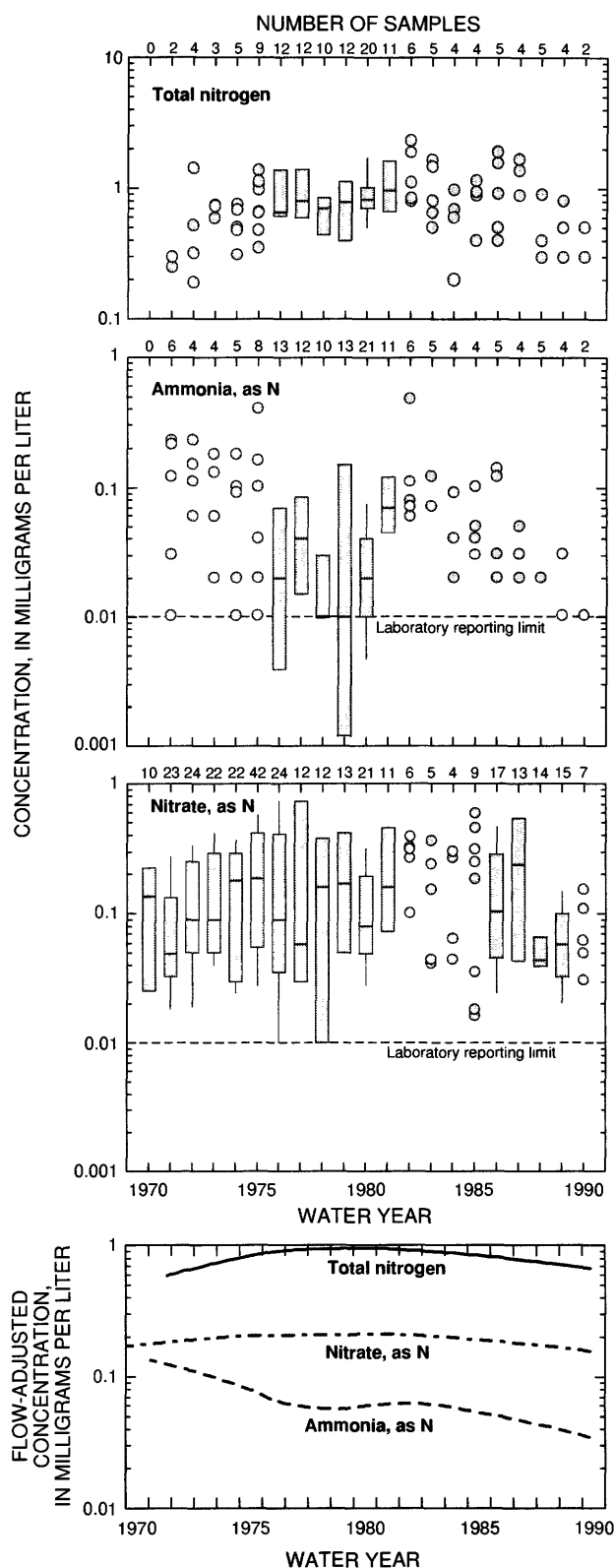


Figure 6. Yearly concentrations and study-period trends of total nitrogen, ammonia, and nitrate for Carson River near Fort Churchill, Nev., water year 1970 through April 1990.

were less than 0.14 mg/L as N (90th percentile). Flow-adjusted ammonia concentrations decreased from about 0.13 mg/L as N in 1971 to about 0.03 mg/L as N in 1990 (fig. 6). The decrease in ammonia probably was due to decreased discharge of sewage effluent during the late 1970's to mid-1980's. After 1987, sewage was no longer discharged to the Carson River (Gary Hoffman, Carson City Utility Department, oral commun., 1993). Nitrate concentrations in samples from the Fort Churchill site generally were less than 0.46 mg/L as N (90th percentile; table 4). Flow-adjusted nitrate concentrations showed little variability during the study period (fig. 6). Nitrate concentrations in samples collected from the West Fork Carson River at Paynesville (fig. 7) were generally less

than 0.14 mg/L as N (90th percentile; table 4). Flow-adjusted nitrate concentrations have decreased slightly at the Paynesville site since about 1979 (fig. 7).

Total-phosphorus concentrations in water samples from the Carson River near Fort Churchill (fig. 8) were commonly less than 0.40 mg/L (90th percentile; table 4). Orthophosphate concentrations were commonly less than 0.22 mg/L as P (90th percentile). Flow-adjusted total-phosphorus concentrations at the Fort Churchill site decreased from about 0.30 mg/L in 1971 to about 0.15 mg/L in April 1990 (fig. 8). Flow-adjusted orthophosphate concentrations have decreased slightly since the late 1970's when discharge

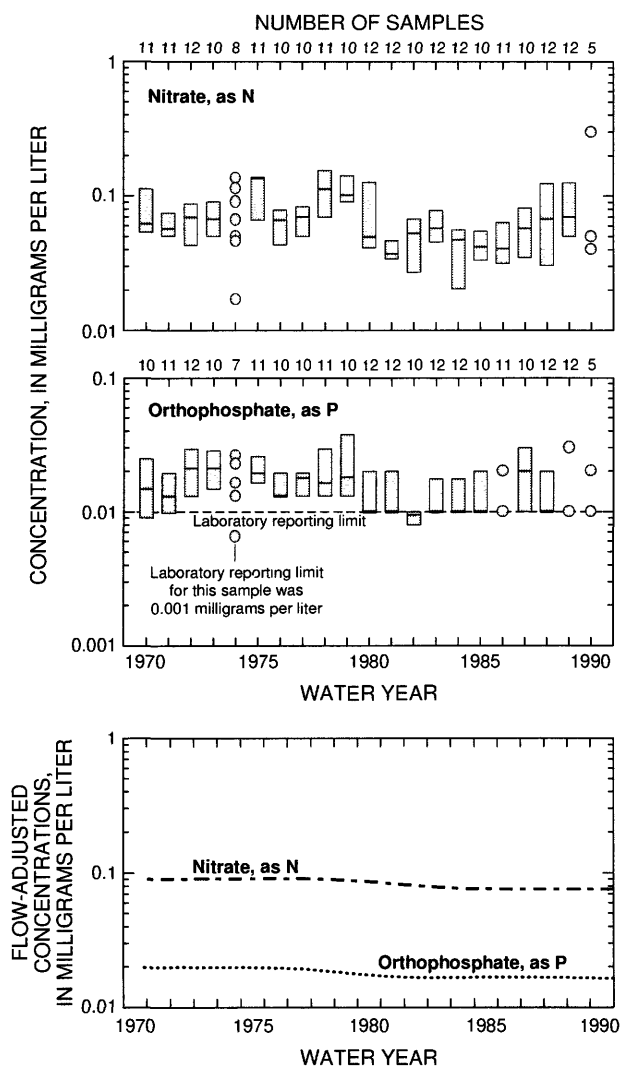


Figure 7. Yearly concentrations and study-period trends of nitrate and orthophosphate for West Fork Carson River at Paynesville, Calif., water year 1970 through April 1990.

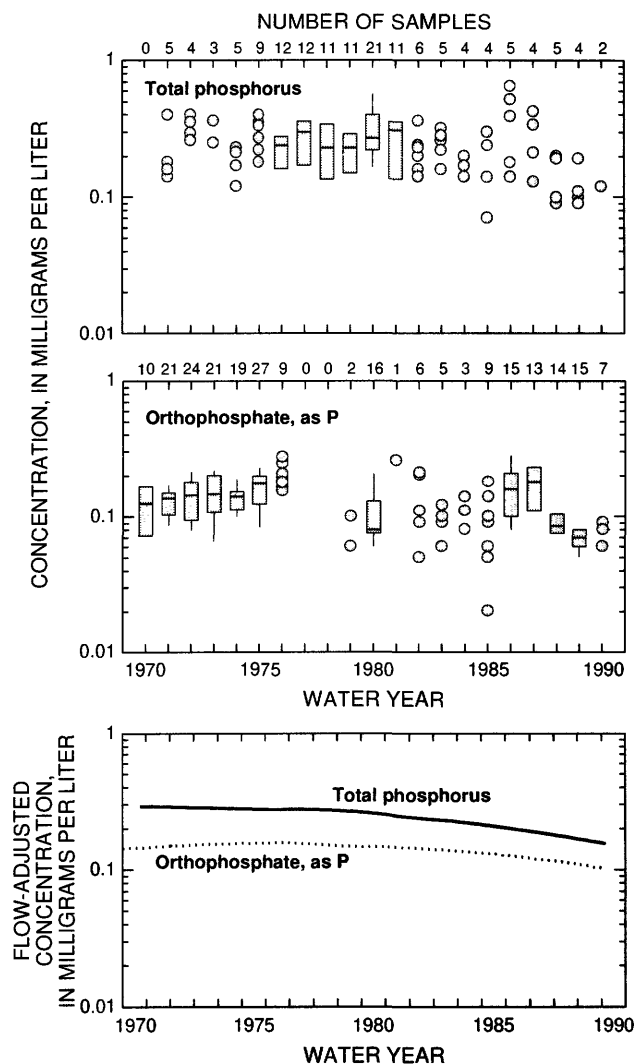


Figure 8. Yearly concentrations and study-period trends of total phosphorus and orthophosphate for Carson River near Fort Churchill, Nev., water year 1970 through April 1990.

of sewage effluent to the Carson River began to decrease (Gary Hoffman, Carson City Utility Department, oral commun., 1993).

Orthophosphate concentrations at the Paynesville site (fig. 7) are commonly less than 0.03 mg/L as P (90th percentile). Flow-adjusted orthophosphate concentrations have decreased slightly since about 1979 (fig. 7).

Annual Trends

Total-nitrogen, ammonia, and nitrate concentrations at the Fort Churchill site vary seasonally. The flow-adjusted concentrations of these three constituents were highest in winter and lowest in summer (fig. 9). Results of nonparametric correlation analysis, which detects monotonic relations between two variables, indicates that flow-adjusted total-nitrogen concentrations varied directly with seasonal changes ($r = 0.64$, p less than 0.001), inversely with water temperature ($r = -0.62$, p less than 0.001), and directly with dissolved oxygen concentrations ($r = 0.52$, p less than 0.001) in streamflow. Flow-adjusted nitrate concentrations at the Paynesville site showed little annual variation during the study period (fig. 10).

Flow-adjusted nitrate concentrations at the Fort Churchill site were highest in the winter when the water temperatures were low and dissolved oxygen concentrations were high, but lowest during the summer when water temperatures were high and dissolved-oxygen concentrations were low (fig. 11). These relations suggest that biological uptake and processing of nitrogen species was dependent on water temperature (Snoeyink and Jenkins, 1980, p. 405). Biological activity in the form of algal and aquatic macrophyte production was probably a major factor in the monthly differences in total-nitrogen, ammonia, and nitrate concentrations measured in samples from the Fort Churchill site. Also, the covarying behavior of the nitrogen species (fig. 9) suggests oxidation of nitrogen (ammonification and nitrification) during the summer months. These processes reduce total-nitrogen and ammonia concentrations, and increase nitrate concentrations; but increased uptake of nitrate by algae and aquatic macrophytes reduces nitrate concentrations.

Total-phosphorus and orthophosphate concentrations at the Carson River near Fort Churchill exhibit seasonal differences (fig. 12), but not as much as seen in nitrogen concentrations. Flow-adjusted concentrations were lowest during summer and autumn and highest during winter and spring. The annual trend of

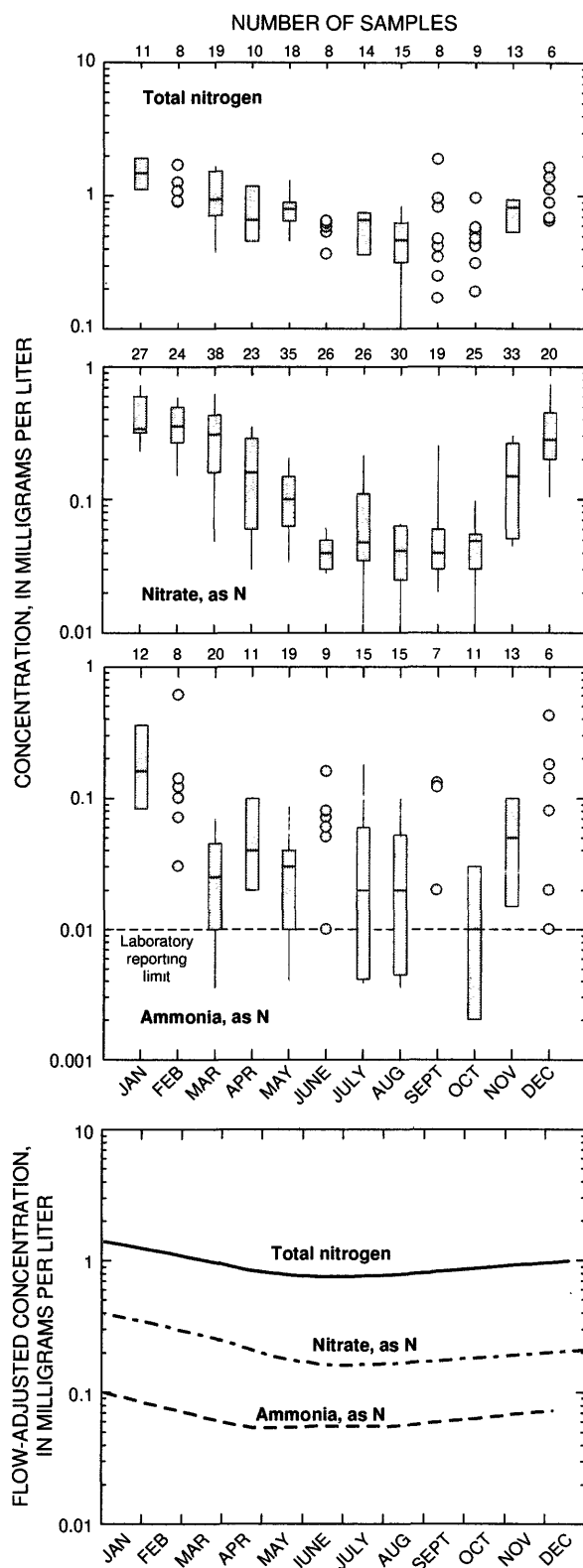


Figure 9. Monthly concentrations and annual trends of total nitrogen, nitrate, and ammonia for Carson River near Fort Churchill, Nev., water year 1970 through April 1990.

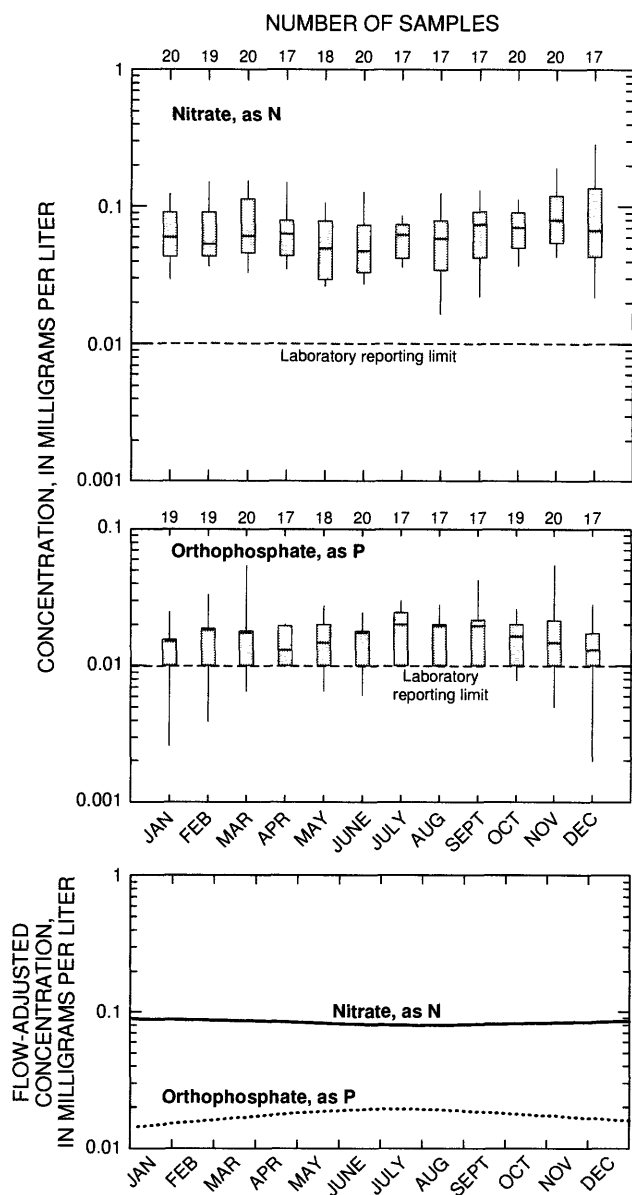


Figure 10. Monthly concentrations and annual trends of nitrate and orthophosphate for West Fork Carson River at Paynesville, Calif., water year 1970 through April 1990.

flow-adjusted orthophosphate concentrations (fig. 12) for the Carson River near Fort Churchill showed only slight seasonal variation during the study period. Flow-adjusted orthophosphate concentrations were lowest in summer and highest in autumn. Biological activity probably affects phosphorus concentrations as it does nitrogen concentrations, but not as much.

Orthophosphate concentrations at the Paynesville site showed only slight seasonal differences (fig. 10). Ninety percent of the samples collected during the

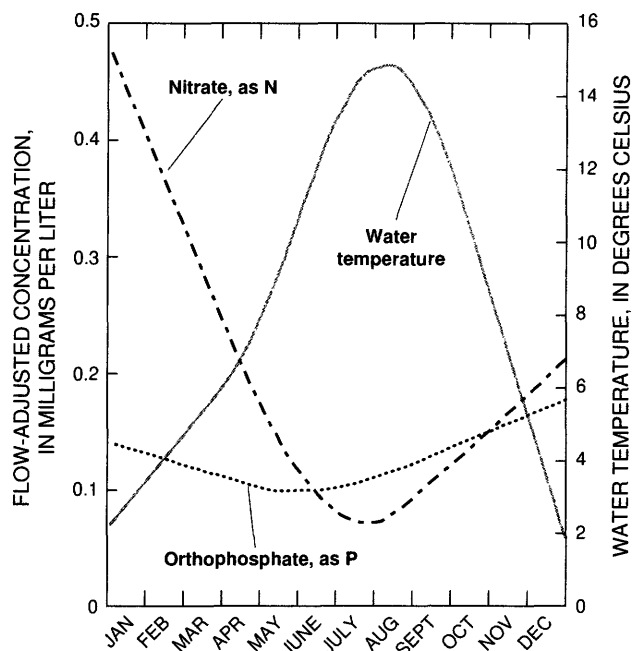


Figure 11. Annual trends of nitrate, orthophosphate, and water temperature for Carson River near Fort Churchill, Nev., water year 1970 through April 1990.

study period had orthophosphate concentrations less than or equal to 0.03 mg/L as P (table 4). Generally, the variation in median orthophosphate concentrations was less than 0.01 mg/L as P, a magnitude that is similar to normal analytical error. Flow-adjusted orthophosphate concentrations at the Paynesville site were slightly higher during the summer.

In many rivers, particularly those that are nutrient rich, diatom populations often increase in the spring. Such a response usually depletes a river of dissolved phosphorus species, such as orthophosphate (Hynes, 1970, p. 70). Early spring blooms of diatoms in the Carson River at Fort Churchill may be responsible for the slightly lower flow-adjusted orthophosphate concentrations in the spring (fig. 12).

Nutrient Concentrations and Streamflow

The relations between nutrient concentrations and streamflow were evaluated by comparing concentrations to percentiles of daily mean streamflow at each site for the study period. Nutrient concentrations were plotted against an associated percentile of flow. LOW-ESS smooth lines were constructed to show the trend in nutrient concentrations during the study period flow regime. Using percentiles of daily mean flow rather

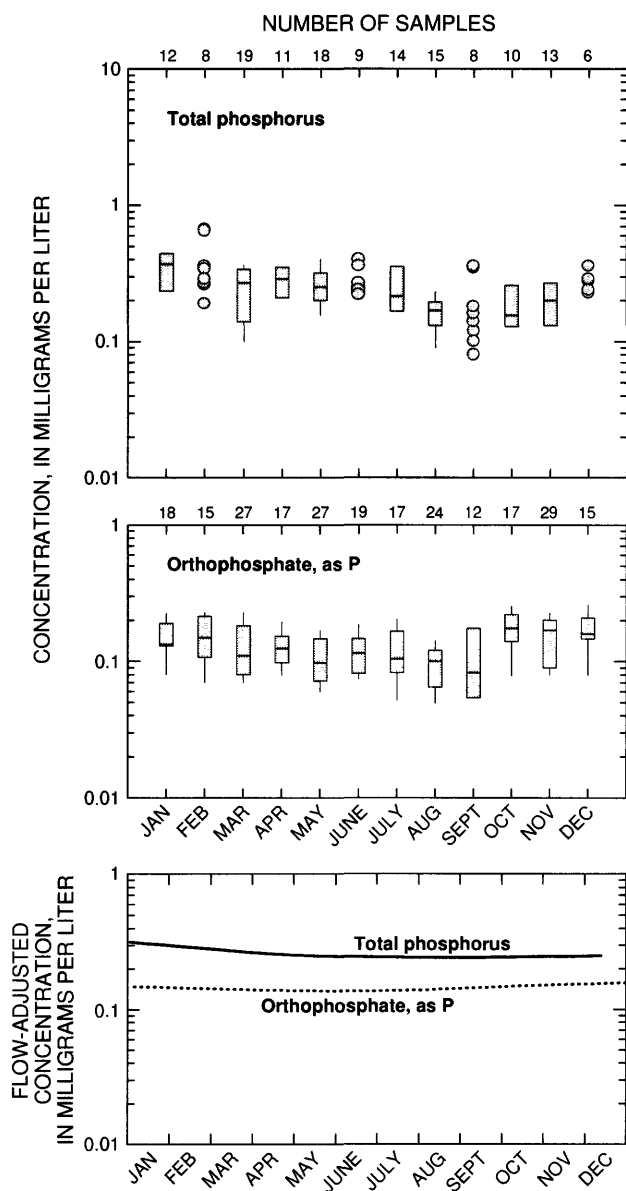


Figure 12. Monthly concentrations and annual trends of total phosphorus and orthophosphate for Carson River near Fort Churchill, Nev., water year 1970 through April 1990.

than actual streamflow values enabled the comparison of nutrient behavior among sites, because the streamflow at each site was standardized.

The relations between nutrient concentrations and streamflow were markedly different for the Paynesville and Fort Churchill sites. Nitrate concentrations at the Paynesville site decreased as streamflow increased cause dilution (fig. 13). At the Fort Churchill site, nitrate concentrations tended to increase until streamflow exceeded the volume that represents about

the 60th percentile, whereupon the nitrate concentrations decreased as streamflow increased causing dilution (fig. 13). This response may represent a “flush” of nitrates from surface runoff (including irrigation-return flows) or increases in the release of treated sewage effluent discharged to the river during the study period. Total-nitrogen concentrations increased as daily mean flow increased at the Fort Churchill site; the increased concentrations may be the result of streambed and bank erosion at high flows and the subsequent release of organic matter from sediment storage. Ammonia concentrations at the Fort Churchill site were unchanged throughout the flow regime (fig. 13).

Phosphorus concentrations also varied with changes in streamflow at both Carson River sites. The relation between orthophosphate concentrations

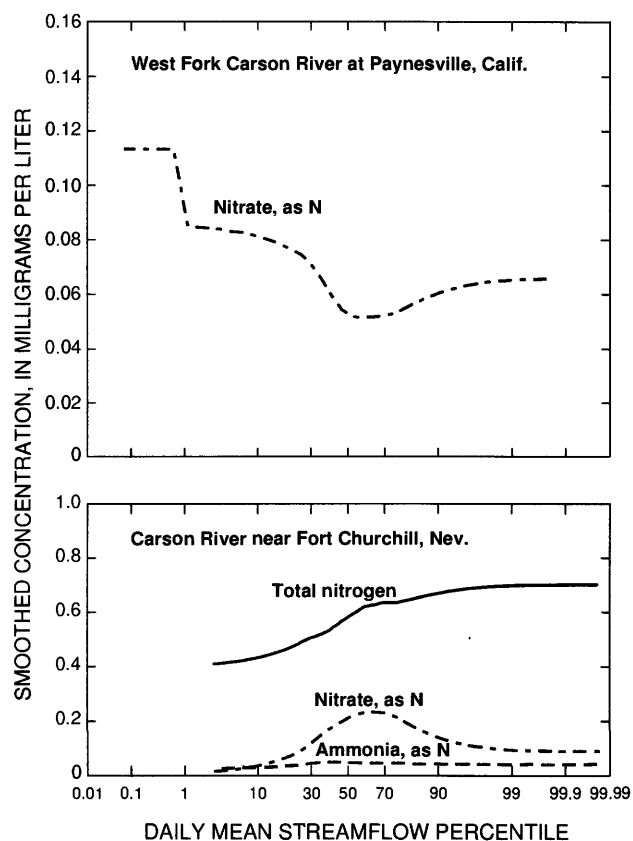


Figure 13. Relations of smoothed concentrations of total nitrogen, ammonia, and nitrate to streamflow percentiles for West Fork Carson River at Paynesville, Calif., and Carson River near Fort Churchill, Nev., water year 1970 through April 1990. Daily mean streamflow values were converted to percentiles to facilitate comparison of relations among stations with different magnitudes of flow; 100th percentile corresponds to highest recorded daily mean flow and 50th percentile corresponds to median daily mean streamflow.

and streamflow at the Paynesville site (fig. 14) was similar to the relation between nitrate concentrations and streamflow. The relations of total-phosphorus and orthophosphate concentrations to streamflow at the Fort Churchill site (fig. 14) were similar to total-nitrogen and nitrate concentrations, respectively, to streamflow.

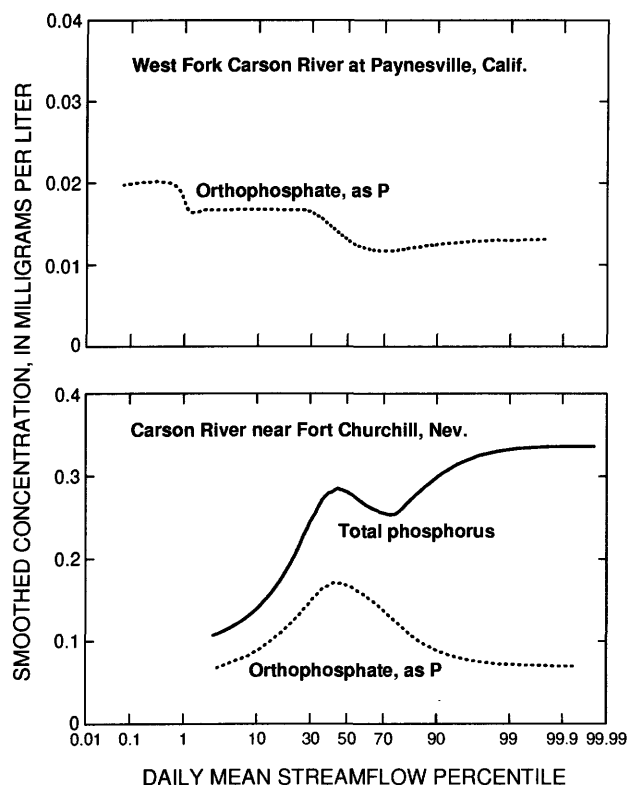


Figure 14. Relations of smoothed concentrations of total phosphorus and orthophosphate to streamflow percentiles for West Fork Carson River at Paynesville, Calif., and Carson River near Fort Churchill, Nev., water year 1970 through April 1990. Daily mean streamflow values were converted to percentiles to facilitate comparison of relations among stations with different magnitudes of flow; 100th percentile corresponds to highest recorded daily mean flow and 50th percentile corresponds to median daily mean streamflow.

Nutrient Loads

Total-nitrogen and total-phosphorus loads transported in the Carson River during the period of study were calculated at the Fort Churchill site, and represent the loads entering Lahontan Reservoir. Equations used to calculate loads are given in table 3. Total-nitrogen and total-phosphorus loads were not calculated at the Gardnerville site on the East Fork Carson River nor at

the Woodfords site on the West Fork Carson River because fewer than 40 samples had been collected at each site. The minimum number of samples needed to calculate annual loads of nutrients is 40 (Dennis Helsel, U.S. Geological Survey, written commun., 1992). Total-nitrogen and total-phosphorus concentrations at the Paynesville site on the West Fork Carson River were not used for analysis because the grab-sample method of collection was used.

The total-nitrogen and total-phosphorus loads were strongly related to the flow regime on an annual and monthly basis because the amount of streamflow determines how much can be transported. The mean annual total-nitrogen load for water years 1970-89 was estimated to be 370 tons, and the mean annual total-phosphorus load for the study period was estimated to be 90 tons (fig. 15). During the study period, the annual total-nitrogen loads ranged from less than 50 to more than 1,000 tons (fig. 15). The annual total-phosphorus loads ranged from less than 15 to more than 400 tons (fig. 15). The monthly total-nitrogen and total-phosphorus loads were lowest in August and September when streamflow was lowest and were highest during May and June when streamflow was highest owing to snowmelt (fig. 16). The monthly total-nitrogen loads ranged from less than 5 to more than 70 tons. The monthly total-phosphorus loads ranged from less than 1 to more than 20 tons (fig. 16).

Garcia and Carman (1986) estimated loads of total nitrogen and total phosphorus transported by the Carson River near Fort Churchill during water year 1980. Those loads were computed by using a time-weighted average method on data collected during water year 1980. The computed loads of about 670 tons of total nitrogen and 230 tons of total phosphorus are larger than loads computed for this study (fig. 15).

NUTRIENT CONCENTRATIONS AND LOADS IN THE TRUCKEE RIVER BASIN

In the Lake Tahoe Basin, both point and non-point sources of nutrients are present. All the communities in the basin are served by municipal wastewater-treatment facilities. No septic systems are allowed in the basin. All treatment facilities transport treated sewage effluent out of the Lake Tahoe Basin for disposal. Potential point and non-point sources of nutrients are abandoned septic tanks, leaky sewer

pipes, and urban runoff in Crystal Bay, Incline Village, and Stateline, Nev.; and Homewood, Kings Beach, South Lake Tahoe, and Tahoe City, Calif.

Information on water-quality sampling sites in the Lake Tahoe Basin is given in appendix A and locations are shown on pl. 2. Ten of these sites were selected to describe the areal distribution of selected nitrogen and phosphorus species in the basin (table 5).

Four of these sites were selected for trend analysis—Meeks Creek near Tahoe City, Calif. (site 79, pl. 2 and app. A), Blackwood Creek near Tahoe City, Calif. (site 83), Third Creek near Crystal Bay, Nev. (site 93), and Incline Creek near Crystal Bay, Nev. (site 96). Meeks Creek and Blackwood Creek drain small watersheds on the west side of Lake Tahoe, and Third and Incline Creeks drain small watersheds on the northeast side (pl. 2). Because of the more dilute water chemistry in

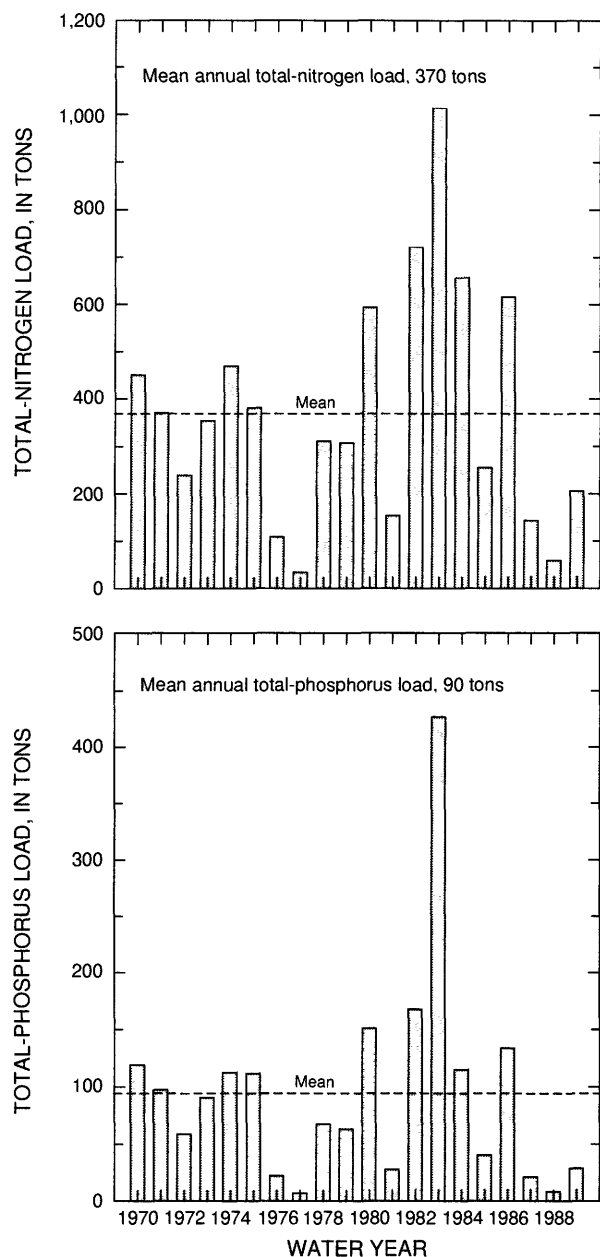


Figure 15. Yearly total-nitrogen and total-phosphorus loads for Carson River near Fort Churchill, Nev., water years 1970-89.

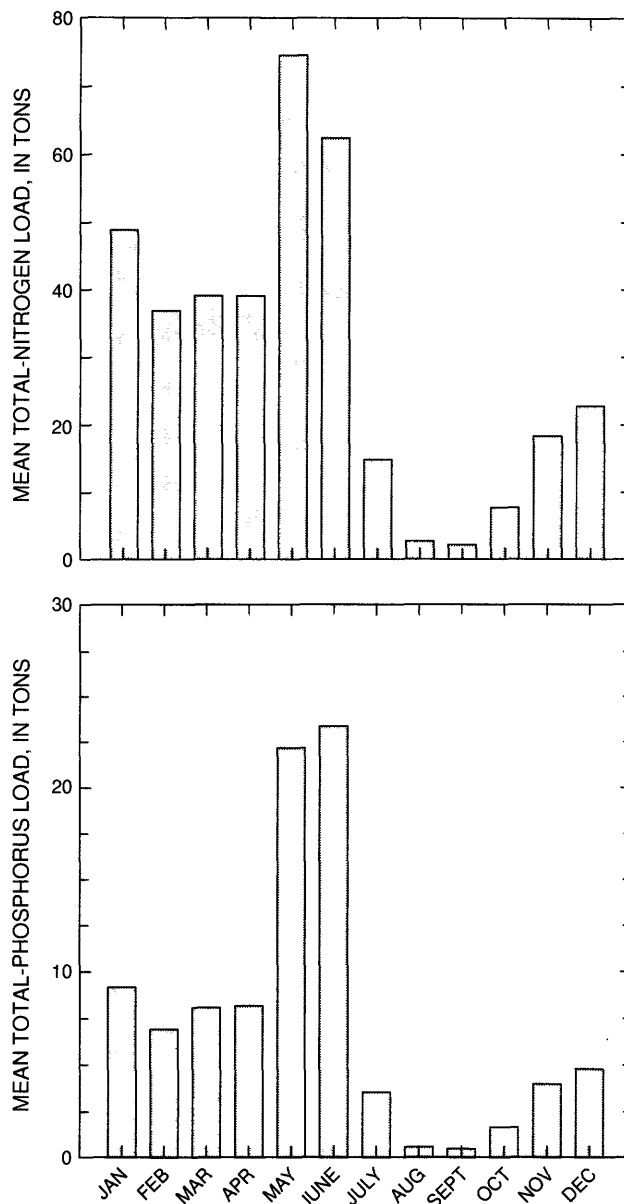


Figure 16. Mean monthly total-nitrogen and total-phosphorus loads for Carson River near Fort Churchill, Nev., water years 1970-89.

Table 5. Statistical summaries of nitrogen and phosphorus in water samples collected at 10 surface-water sites in the Lake Tahoe Basin, water year 1970 through April 1990

[Values in milligrams per liter. When number of samples with concentrations below laboratory reporting limit is greater than 10 percent of total samples, robust probability methods (Helsel and Hirsch, 1992) or maximum-likelihood methods (Helsel and Cohn, 1988) were used to estimate values below reporting limit prior to calculating percentiles. Symbol: --, not applicable because of insufficient data for calculation.]

Site number (pl. 2)	Site name	Number of samples in relation to reporting limit		Minimum ¹	Maximum	Percentile ²					
		Above	Below			10th	25th	50th (median)	75th	90th	
Total nitrogen											
80	General Creek near Meeks Bay, Calif.	1	0	0.07	--	--	--	--	--	--	--
83	Blackwood Creek near Tahoe City, Calif.	2	0	.08	0.4	--	--	--	--	--	--
93	Third Creek near Crystal Bay, Nev.	37	0	.08	3.8	0.11	0.17	0.55	1.2	1.7	
96	Incline Creek near Crystal Bay, Nev.	36	0	.10	2.9	.15	.24	.63	1.1	1.9	
102	Glenbrook Creek at Glenbrook, Nev.	16	0	.08	2.1	.08	.18	.34	.79	1.9	
105	Edgewood Creek at Lake Tahoe, Calif.	16	0	.21	1.1	.26	.31	.38	.72	1.1	
106	Trout Creek at USFS Road 12N01, Calif.	2	0	.10	.12	--	--	--	--	--	
Ammonia as nitrogen											
80	General Creek near Meeks Bay, Calif.	18	0	.002	.020	.002	.004	.004	.005	.020	
83	Blackwood Creek near Tahoe City, Calif.	17	2	<.001	.010	.002	.003	.004	.005	.008	
93	Third Creek near Crystal Bay, Nev.	85	20	<.001	1.1	<.001	.001	.003	.008	.027	
96	Incline Creek near Crystal Bay, Nev.	80	28	<.001	1.2	<.001	<.001	.006	.012	.080	
102	Glenbrook Creek at Glenbrook, Nev.	98	3	<.001	.100	.002	.004	.009	.030	.048	
105	Edgewood Creek at Lake Tahoe, Calif.	61	1	<.001	.12	.002	.003	.006	.045	.071	
106	Trout Creek at USFS Road 12N01, Calif.	5	1	<.002	.010	--	--	--	--	--	
Nitrate as nitrogen											
74	Big Meadow Creek above Cookhouse Meadow	143	1	<.001	.06	.002	.004	.007	.015	.028	
79	Meeks Creek near Tahoe City, Calif.	104	2	<.001	.024	.002	.003	.004	.007	.012	
80	General Creek near Meeks Bay, Calif.	30	0	.001	.030	.002	.005	.009	.011	.020	
83	Blackwood Creek near Tahoe City, Calif.	161	0	.002	.14	.008	.013	.024	.046	.073	
90	Wood Creek at Lakeshore Blvd., Nev.	67	40	<.002	.500	.002	.005	.023	.090	.14	
93	Third Creek near Crystal Bay, Nev.	168	47	<.003	.56	<.003	<.003	.010	.045	.10	
96	Incline Creek near Crystal Bay, Nev.	98	1	<.007	.16	.010	.020	.040	.070	.11	
102	Glenbrook Creek at Glenbrook, Nev.	88	0	.002	.36	.007	.010	.020	.040	.080	
105	Edgewood Creek at Lake Tahoe, Calif.	70	0	.001	.14	.006	.010	.030	.050	.085	
106	Trout Creek at USFS Road 12N01, Calif.	134	1	<.001	.050	.003	.005	.008	.010	.020	

Table 5. Statistical summaries of nitrogen and phosphorus in water samples collected at 10 surface-water sites in the Lake Tahoe Basin, water year 1970 through April 1990—Continued

Site number (pl. 2)	Site name	Number of samples in relation to reporting limit		Minimum ¹	Maximum	Percentile ²				
		Above	Below			10th	25th	50th (median)	75th	90th
Total phosphorus										
80	General Creek near Meeks Bay, Calif.	15	1	<0.01	0.06	0.01	0.02	0.03	0.04	0.05
83	Blackwood Creek near Tahoe City, Calif.	16	0	.01	.06	.01	.02	.03	.04	.04
93	Third Creek near Crystal Bay, Nev.	98	0	.005	.69	.007	.01	.03	.06	.26
96	Incline Creek near Crystal Bay, Nev.	103	0	.006	.83	.011	.02	.04	.11	.31
102	Glenbrook Creek at Glenbrook, Nev.	100	0	.008	.55	.009	.01	.03	.07	.14
105	Edgewood Creek at Lake Tahoe, Nev.	61	0	.02	.30	.03	.04	.05	.08	.12
Orthophosphate as phosphorus										
74	Big Meadow Creek above Cookhouse Meadow	146	0	.002	.020	.003	.005	.005	.008	.010
79	Meeks Creek near Tahoe City, Calif.	96	11	<.001	.040	.002	.002	.003	.005	.014
80	General Creek near Meeks Bay, Calif.	29	4	<.002	.030	.004	.009	.012	.015	.018
83	Blackwood Creek near Tahoe City, Calif.	156	3	<.001	.010	.002	.003	.003	.005	.008
90	Wood Creek at Lakeshore Blvd., Nev.	104	3	.003	.24	.010	.016	.020	.026	.039
93	Third Creek near Crystal Bay, Nev.	214	5	<.002	.25	.005	.010	.010	.020	.037
96	Incline Creek near Crystal Bay, Nev.	105	1	<.003	.25	.005	.009	.011	.019	.050
102	Glenbrook Creek at Glenbrook, Nev.	97	2	<.003	.10	.005	.007	.010	.014	.024
105	Edgewood Creek at Lake Tahoe, Nev.	69	0	.004	.07	.006	.010	.015	.029	.038
106	Trout Creek at USFS Road 12N01, Calif.	134	0	.003	.03	.007	.008	.008	.010	.012

¹ Laboratory reporting limits are indicated by the "less than" symbol, "<".

² Percentiles for total nitrogen, ammonia, and total phosphorus are for samples collected and analyzed by U.S. Geological Survey. These constituents are not comparable to those in samples collected by other agencies because USGS samples were collected using depth and horizontal integration method, whereas other agencies generally used a "grab-sampling" technique to collect samples. According to Martin and others (1992), "grab" methods underrepresent total nitrogen, ammonia, and total phosphorus concentrations. Percentiles for nitrate and orthophosphate include samples collected and analyzed by the U.S. Geological Survey and other agencies.

the basin, MDL's for nutrient samples are generally an order of magnitude lower than MDL's in the Carson River Basin.

Discharge of effluent in the Truckee River Basin downstream from Lake Tahoe is from wastewater and sewage-treatment plants, urban storm drains, basement dewatering, aquaculture discharges, excess intake water at water-treatment facilities, and landfill drainage. The only two sewage-treatment plants currently in operation in the Truckee River Basin are operated by the Tahoe-Truckee Sanitation Agency (TTSA) and the Truckee Meadows Water Reclamation Facility (TMWRF). During the study period, the TTSA treated effluent on-site and either disposed of effluent in leach fields or applied the treated effluent to land surfaces. A plume of nitrogen-enriched ground water from this land application is intercepted by Martis Creek, a small tributary to the Truckee River (McLaren, 1977, p. III-6). Martis Creek in this area contains large amounts of filamentous algae, which suggests nutrient enrichment.

The TMWRF discharges into Steamboat Creek just upstream from its confluence with the Truckee River. Since 1982, the TMWRF has implemented tertiary treatment of sewage effluent. This treatment includes the physical, chemical, and biological removal of ammonia, nitrate, and phosphorus. However, during the study period, the population served by the TMWRF increased by nearly 120 percent from 150,000 people in 1970 to 325,000 in 1990. Thus, much of the benefit of tertiary treatment has been masked by large increases in the amount of sewage processed. The annual total-nitrogen and total-phosphorus loads in sewage effluent from the TMWRF during 1983-90 are given in table 6.

Nutrient water-quality sites in the Truckee River Basin downstream from Lake Tahoe are listed in appendix A and shown on plate 2. Some of these are USGS sites associated with current or past streamflow-gaging stations. The other sites are used as water-quality sampling sites by multiple agencies including USGS, Nevada Division of Environmental Protection, U.S. Forest Service, and Desert Research Institute. Nine of these sites were selected to describe areal distribution of selected nitrogen and phosphorus species—Martis Creek near Truckee, Calif. (site 130, pl. 2 and app. A), Sagehen Creek near Truckee, Calif. (site 132), Truckee River at Farad, Calif. (site 138), Truckee River near Sparks, Nev. (site 149), Truckee River at Lockwood, Nev. (site 158), Truckee River at Clark, Nev. (site 160), Truckee River at Wadsworth, Nev.

Table 6. Total nitrogen and phosphorus loads discharged by Truckee Meadows Water Reclamation Facility, 1983-90

Year	Annual load ¹ (tons)	
	Total nitrogen	Total phosphorus
1983	520	21.9
1984	588	32.8
1985	613	16.4
1986	699	13.1
1987	780	15.7
1988	592	13.8
1989	137	8.38
1990	76.8	14.4

¹ Load estimates were provided by James J. Cooper, Nevada Division of Environmental Protection (written commun., 1994). Kjeldahl nitrogen concentration and nitrate plus nitrite were used to compute total nitrogen loads. Total annual load was computed by multiplying average of monthly average concentrations for each year by total discharge for the year, including appropriate conversion factors.

(site 169), Truckee River near Nixon, Nev. (site 171), and Truckee River at Marble Bluff Dam, Nev. (site 174). Only four sites on the Truckee River had a sufficient number of nutrient samples to assess study-period trends in nutrient concentrations—Truckee River at Farad, Calif., near Sparks, Nev., at Lockwood, Nev., and near Nixon, Nev.

Areal Distribution of Nutrient Concentrations

The 10 sites listed in table 5 represent most of the larger watersheds in the Lake Tahoe Basin and give an accurate areal depiction of nutrient concentrations in the basin.

The concentrations of nitrogen species in streams within the Lake Tahoe Basin generally were small and did not indicate nitrogen enrichment (table 5). Although the data base is limited, median total-nitrogen concentrations ranged from 0.34 to 0.63 mg/L, median ammonia concentrations ranged from 0.003 to 0.009 mg/L as N, and median nitrate concentrations ranged from 0.004 to 0.040 mg/L as N. Median concentrations of total nitrogen and nitrate (0.63 and 0.040 mg/L, respectively) in samples from Incline Creek, which drains the Incline Village area, were the highest in the basin.

Statistical summaries of total-nitrogen, ammonia, and nitrate concentrations analyzed in samples collected during the study period at nine surface-water sites in the Truckee River Basin downstream from Lake Tahoe are given in table 7. Samples from Sagehen Creek (site 132, pl. 2 and app. A) and the Truckee River at Farad (site 138) typically had the lowest nutrient concentrations in the basin. The Sagehen Creek site is a USGS Hydrologic Benchmark Network Station in the Sierra Nevada. Median total-nitrogen and nitrate concentrations at Farad (0.36 and 0.06 mg/L as N, respectively) were less than those at Sagehen Creek (0.50 and 0.07 mg/L as N, respectively). The median ammonia concentration at Farad (0.02 mg/L) was higher than that at Sagehen Creek (less than 0.01 mg/L). Nitrogen species concentrations at Martis Creek near Truckee (site 130), a tributary to the Truckee River, are markedly higher than concentrations at Sagehen Creek and the Truckee River at Farad. Land application of sewage effluent by the Tahoe-Truckee Sanitation Agency is a source of nitrogen enrichment to Martis Creek.

Most nitrogen species concentrations at other sites on the Truckee River were higher than those for Sagehen Creek or the Truckee River at Farad. Total-nitrogen data were limited for the Truckee River near Sparks; however, the median ammonia concentration was 0.04 mg/L as N, and the median nitrate concentration was 0.02 mg/L as N (table 7). Nitrogen species concentrations for the Truckee River at Lockwood and downstream sites are enriched by the discharge of treated sewage effluent from the TMWRF (table 7). Median total-nitrogen and nitrate concentrations at Lockwood (1.4 and 0.20 mg/L, respectively) and Clark (1.8 and 0.38 mg/L, respectively) were as much as 5 times higher than those at Farad (table 7), and ammonia concentrations (0.51 and 0.30 mg/L, respectively) were as much as 25 times higher than at Farad.

Median concentrations of total phosphorus for stream sites sampled in the Lake Tahoe basin ranged from 0.03 to 0.05 mg/L (table 5). The total-phosphorus concentrations were highest in samples collected from Third and Incline Creeks—two of the most urbanized watersheds in the Lake Tahoe Basin. The highest total-phosphorus concentration measured in the basin was 0.83 mg/L in a sample from Incline Creek (site 96; pl. 2 and app. A). Median concentrations of orthophosphate ranged from 0.003 to 0.020 mg/L as P. The highest orthophosphate concentrations were measured in

samples from Wood (site 90), Third (site 93), and Incline Creeks, (0.24, 0.25, and 0.25 mg/L as P, respectively), which drain the Incline Village urban area.

In the Truckee River Basin downstream from Lake Tahoe, the median total-phosphorus concentration at the Truckee River at Farad was 0.02 mg/L, identical to the median concentration at Sagehen Creek (table 7). The median orthophosphate concentration at Farad was less than 0.01 mg/L as P, which was comparable to the concentration at Sagehen Creek. The median total-phosphorus concentration for the Truckee River near Sparks was 0.03 mg/L, and the median orthophosphate concentration was 0.01 mg/L as P (table 7). Median concentrations of total phosphorus and orthophosphate at Lockwood (0.19 and 0.05 mg/L as P, respectively) and the sites downstream were 10 to 25 times higher than those at Sagehen Creek and Farad because of enrichment by the discharge of treated sewage from the TMWRF.

Downstream Changes in Truckee River Nutrient Concentrations

One of the goals of the areal analysis of nutrients in the surface water of the Truckee River Basin is to evaluate changes in nutrient concentrations at locations along the river profile, beginning in the headwater area and ending at the inlet to Pyramid Lake. Nutrient concentrations change as the river flows through different hydrologic areas and different land uses. The distribution and downstream changes in nitrate and orthophosphate concentrations at sites on the Truckee River are shown in figure 17. The nitrate and orthophosphate concentrations were used because these nutrients are not as affected by sampling methods as are total-nitrogen, ammonia, and total-phosphorus concentrations (Martin and others, 1992). Many of the nitrate and orthophosphate samples used in the profile were collected using the grab-sample method.

Nitrate concentrations generally were low at Farad (site 138, pl. 2 and app. A) and increased slightly between Farad and Sparks (site 149; fig. 17). Compared to concentrations near Sparks, nitrate concentrations were about two times higher at Lockwood (site 158), and about four times higher at Clark (site 160). Nitrate concentrations decreased downstream from Clark to Marble Bluff Dam (site 174), just upstream from Pyramid Lake, where the concentrations were similar to those observed near Sparks. The discharge of treated sewage effluent from the TMWRF was the

Table 7. Statistical summaries of nitrogen and phosphorus in samples collected at nine surface-water sites in the Truckee River Basin downstream from Lake Tahoe, water year 1970 through April 1990

[Values in milligrams per liter. When number of samples with concentrations below laboratory reporting limit (MDL) was greater than 10 percent of total samples collected, robust probability methods (Helsel and Hirsch, 1992) or maximum-likelihood methods (Helsel and Cohn, 1988) were used to estimate data values below MDL prior to calculating percentiles. Symbol: --, not applicable because of insufficient data above the MDL for calculation]

Site number (pl. 2)	Site name	Number of samples in relation to reporting limit		Minimum ¹	Maximum	Percentiles ²				
		Above	Below			10th	25th	50th (median)	75th	90th
130	Martis Creek near Truckee, Calif.	38	0	0.17	4.7	0.32	0.52	0.86	1.6	2.9
132	Sagehen Creek near Truckee, Calif.	29	0	.07	.8	.21	.33	.50	.60	.70
138	Truckee River at Farad, Calif.	139	0	.01	3.2	.14	.23	.36	.57	.85
149	Truckee River near Sparks, Nev.	14	0	.29	1.3	--	.36	.46	.75	--
158	Truckee River at Lockwood, Nev.	148	0	.25	19.6	.78	1.0	1.4	2.0	2.7
160	Truckee River at Clark, Nev.	63	0	.27	4.2	.43	1.0	1.8	2.3	2.6
169	Truckee River at Wadsworth, Nev.	68	0	.38	3.6	.52	.75	1.2	1.5	1.9
171	Truckee River near Nixon, Nev.	76	0	.31	2.6	.45	.70	.95	1.4	1.9
174	Truckee River at Marble Bluff Dam, Nev.	7	0	.60	10.2	--	--	--	--	--
130	Martis Creek near Truckee, Calif.	47	0	.01	.22	.01	.02	.05	.09	.14
132	Sagehen Creek near Truckee, Calif.	44	5	<.01	.40	<.01	<.01	<.01	.02	.04
138	Truckee River at Farad, Calif.	108	6	<.01	.30	.01	.01	.02	.03	.08
149	Truckee River near Sparks, Nev.	84	11	<.01	.33	<.01	.02	.04	.07	.20
158	Truckee River at Lockwood, Nev.	265	5	<.01	8.9	.05	.13	.51	.90	1.4
160	Truckee River at Clark, Nev.	137	4	<.01	1.7	.02	.06	.30	.62	1.0
169	Truckee River at Wadsworth, Nev.	127	14	<.01	1.1	.01	.03	.06	.24	.41
171	Truckee River near Nixon, Nev.	91	20	<.01	1.8	<.01	<.01	<.01	.12	.25
174	Truckee River at Marble Bluff Dam, Nev.	50	14	<.01	.60	<.01	.02	.04	.10	.31
130	Martis Creek near Truckee, Calif.	37	0	.01	3.8	.01	.04	.20	.53	2.4
132	Sagehen Creek near Truckee, Calif.	43	0	.01	.30	.01	.01	.07	.10	.10
138	Truckee River at Farad, Calif.	314	97	<.01	2.9	.02	.03	.06	.11	.23
149	Truckee River near Sparks, Nev.	263	116	<.01	.74	<.01	<.01	.02	.07	.18
158	Truckee River at Lockwood, Nev.	322	19	<.01	8.9	.08	.12	.20	.35	.72

Table 7. Statistical summaries of nitrogen and phosphorus in samples collected at nine surface-water sites in the Truckee River Basin downstream from Lake Tahoe, water year 1970 through April 1990—Continued

Site number (pl. 2)	Site name	Number of samples in relation to reporting limit	Minimum ¹	Maximum	Percentiles ²					
					10	25	50 (median)	75	90	
Nitrate as nitrogen—Continued										
160	Truckee River at Clark, Nev.	387	11	<0.01	6.3	0.10	0.20	0.38	0.68	1.1
169	Truckee River at Wadsworth, Nev.	309	11	<.01	1.9	.13	.22	.38	.57	.84
171	Truckee River near Nixon, Nev.	125	2	<.01	.90	.06	.20	.33	.50	.65
174	Truckee River at Marble Bluff Dam, Nev.	43	18	<.01	.96	<.01	<.01	.02	.28	.72
Total phosphorus										
130	Martis Creek near Truckee, Calif.	55	0	.01	.10	.02	.03	.04	.05	.07
132	Sagehen Creek near Truckee, Calif.	50	0	.01	.13	.01	.01	.02	.03	.05
138	Truckee River at Farad, Calif.	129	17	.01	.06	<.01	.02	.02	.03	.05
149	Truckee River near Sparks, Nev.	112	0	.01	.40	.02	.02	.03	.05	.07
158	Truckee River at Lockwood, Nev.	276	0	.01	11.0	.07	.09	.19	.37	.60
Orthophosphate as phosphorus										
160	Truckee River at Clark, Nev.	141	0	.03	.75	.05	.06	.08	.10	.15
169	Truckee River at Wadsworth, Nev.	135	0	.01	1.7	.03	.04	.06	.09	.16
171	Truckee River near Nixon, Nev.	114	0	.01	2.1	.05	.09	.20	.30	.39
174	Truckee River at Marble Bluff Dam, Nev.	61	0	.03	1.8	.03	.05	.08	.13	.22
132	Sagehen Creek near Truckee, Calif.	49	2	<.01	.04	<.01	<.01	<.01	.01	.02
138	Truckee River at Farad, Calif.	160	124	<.01	.06	<.01	<.01	<.01	.01	.02
149	Truckee River near Sparks, Nev.	247	44	<.01	.13	<.01	<.01	.01	.03	.04
158	Truckee River at Lockwood, Nev.	167	0	.04	.92	.02	.03	.05	.20	.33
160	Truckee River at Clark, Nev.	304	1	<.01	1.6	.02	.03	.09	.34	.50
169	Truckee River at Wadsworth, Nev.	297	4	<.01	.51	.01	.02	.10	.22	.30
171	Truckee River near Nixon, Nev.	68	7	<.01	.31	.02	.03	.12	.18	.23
174	Truckee River at Marble Bluff Dam, Nev.	51	0	<.01	.23	<.01	.02	.02	.05	.20

¹ USGS laboratory reporting limits in milligrams per liter (mg/L) are indicated by the "less than" symbol, "<".

² Percentiles for total nitrogen, ammonia, and total phosphorus are based on USGS collected and analyzed samples, and samples collected and analyzed by the Truckee Meadows Water Treatment Facility. Samples collected by other agencies may not be comparable because "grab-sampling" methods are used instead of depth-integrated methods. Concentrations of total nitrogen, ammonia, and total phosphorus are thought to be biased low when "grab samples" are collected (Martin and others, 1992).

likely principal cause of the high nitrate concentrations at Lockwood and Clark, but North Truckee Drain and Steamboat Creek also contribute nitrate. The increase in nitrate concentrations between Lockwood and Clark probably was a result of nitrification of ammonia. The large decrease in nitrate concentrations between Clark and Marble Bluff Dam probably was caused by biological uptake and immobilization.

The concentrations of orthophosphate were lowest at Farad and increased between Farad and Lockwood (fig. 17). The increase in orthophosphate concentrations between Farad and Sparks could be a result of urban runoff. The increase between Sparks and Lockwood presumably was caused mostly by the discharge of sewage effluent by the TMWRF.

Temporal Analysis of Nutrient Concentrations

Although the study period for this report spans more than 20 years (water year 1970 through April 1990), the sampling periods at the four selected sites in the Lake Tahoe Basin did not span the full study period. Samples have been collected at Meeks Creek since water year 1979 and at Blackwood Creek since water year 1978. The periods of record for samples collected from Third and Incline Creeks span the study period, but are discontinuous. The major sampling periods for Third and Incline Creeks were water years 1970-73 (Glancy, 1988) and water years 1988 through April 1990; however, different nutrients were sampled for during different periods of record.

Changes in nutrient concentrations during the study period and the annual changes at four sites along the Truckee River were evaluated. Unfortunately, data from several of the sites had uncertainties that could have impaired trend analysis.

Study-Period Trends

Study-period trends were not determined for total nitrogen because of the limited number of samples from which that constituent could be computed (table 5). Although Third and Incline Creeks had the most ammonia data, the few data that were available for water years 1974 through 1987 (fig. 18) precluded

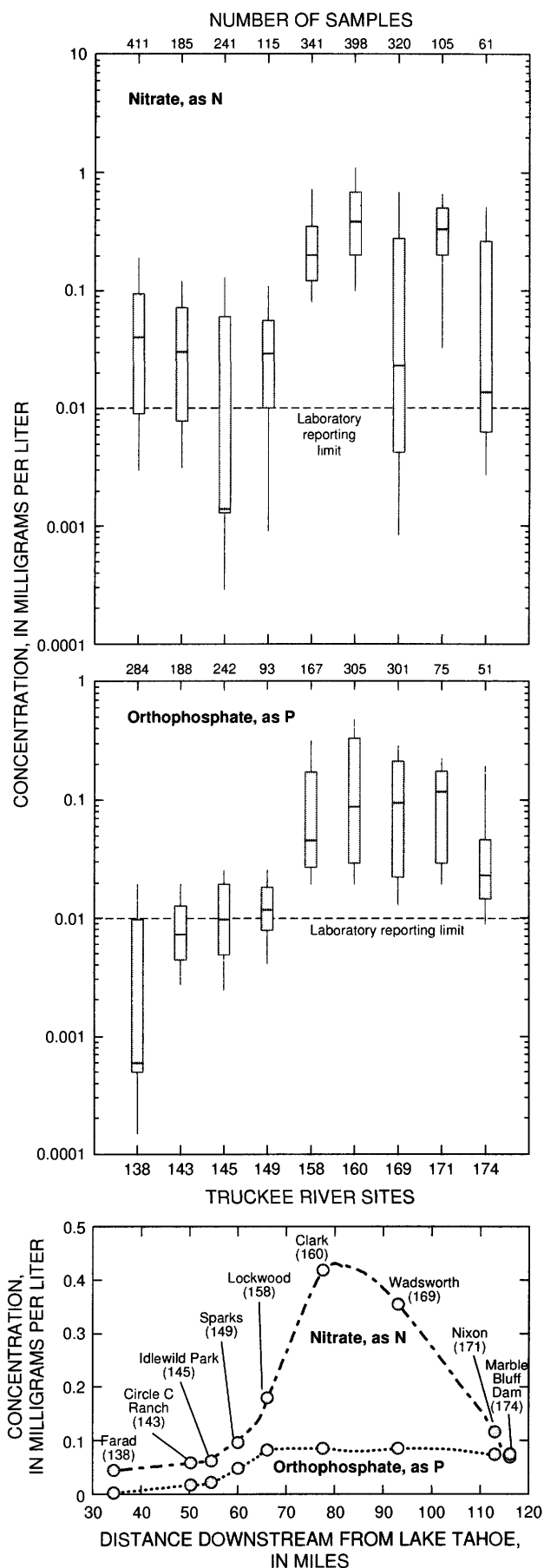


Figure 17. Concentrations and downstream trends of nitrate and orthophosphate for selected water-quality sampling sites on Truckee River, Calif. and Nev., water year 1970 through April 1990.

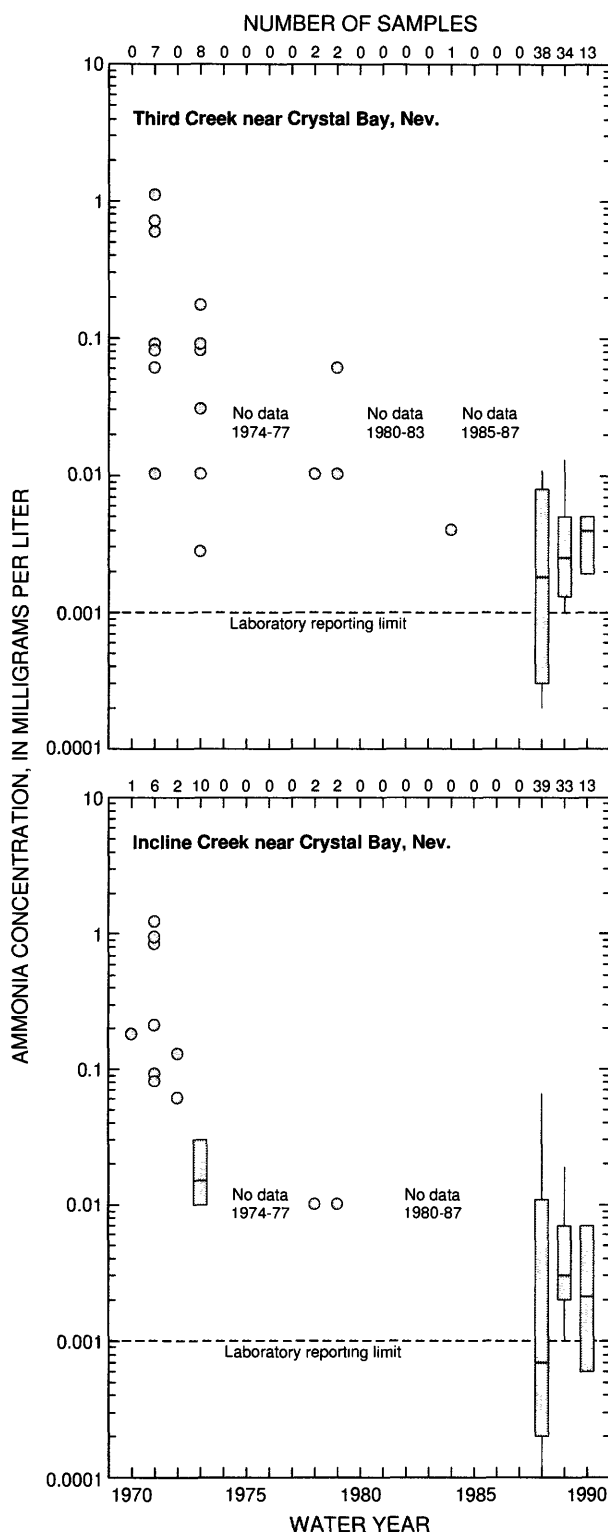


Figure 18. Yearly concentrations of ammonia for Third Creek near Crystal Bay, Nev., and Incline Creek near Crystal Bay, Nev., intermittent samples, water year 1970 through April 1990.

study-period trend analysis. However, enough samples were present for these two sites to allow a time-period comparison of flow-adjusted concentrations using the nonparametric paired t-test. The t-test results show that flow-adjusted ammonia concentrations were significantly higher during water years 1970-73 than during the water year 1988 through April 1990 period in samples from both Third Creek (p equals 0.002) and Incline Creek (p less than 0.001). The higher concentrations in the early 1970's samples could have been caused by the early phases of urban development in Incline Village, which consisted of land clearing and road construction (Glancy, 1988, p. 42).

Boxplots of annual nitrate concentrations in samples collected from Third and Incline Creeks are shown in figure 19. Flow-adjusted nitrate concentrations were significantly higher (p equals 0.047) during the late 1980's in Third Creek than concentrations measured during the early 1970's, but not significantly different (p equals 0.31) in samples from Incline Creek. This difference for the Third Creek watershed could be a result of watershed disruption by two avalanches in February 1986 (Timothy G. Rowe, U.S. Geological Survey, oral commun., 1993). Boxplots of annual nitrate concentrations for samples from Meeks Creek and Blackwood Creek are shown in figures 20 and 21, respectively. Nitrate concentrations (not flow adjusted) for Meeks Creek increased between 1979 and 1985 (fig. 20). The trend after 1985 is not known because of limited data. Flow adjustment of nitrate data from Meeks Creek was not needed because a statistically significant relation with flow did not exist. Flow-adjusted nitrate concentrations for samples from Blackwood Creek have increased since about 1986 (fig. 21).

At most sites along the Truckee River, the sampling intensity and the range in nutrient concentrations varied greatly during the study period. Sample collections ranged from once a year to two or three times a month. The absence of data for several of the years in the study period decreases the reliability of the trend line for those years.

Sites with sufficient data for evaluating study-period trends in ammonia or nitrate include Truckee River at Farad (fig. 22; site 138, pl. 2 and app. A), near Sparks (fig. 23; site 149), at Lockwood (fig. 24; site 158), and near Nixon (fig. 25; site 171). Total-nitrogen data were not sufficient for evaluating study-period trends.

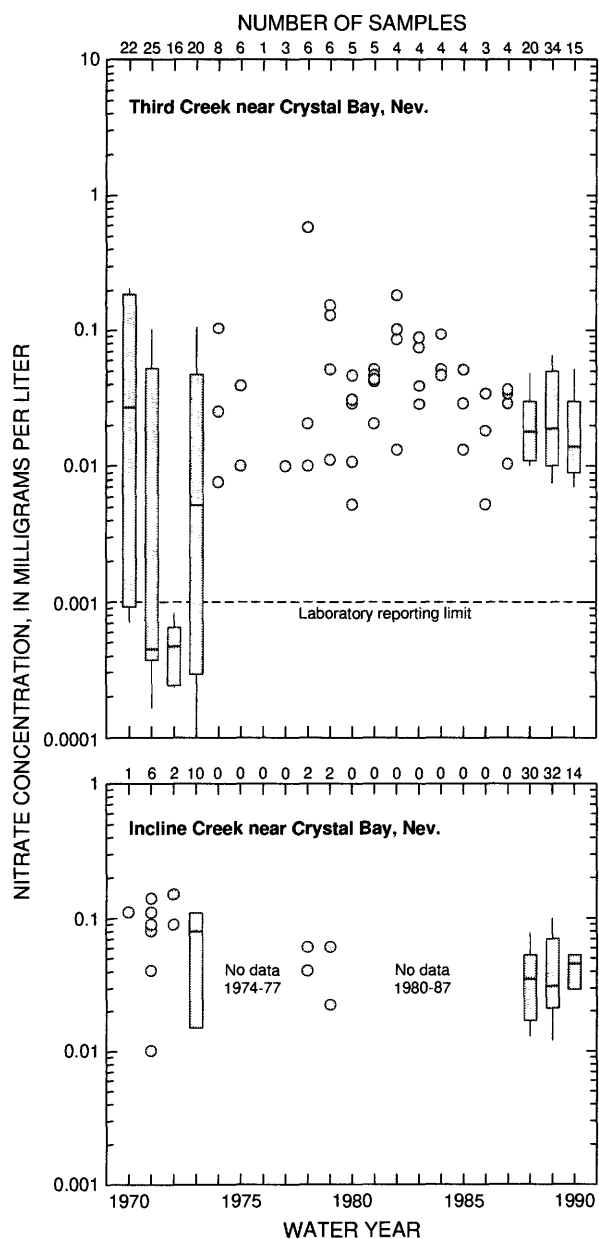


Figure 19. Yearly concentrations of nitrate for Third Creek near Crystal Bay, Nev., and Incline Creek near Crystal Bay, Nev., intermittent samples, water year 1970 through April 1990.

Samples collected at Farad during the study period that were analyzed for ammonia were grab samples. Thus, those samples are not included in the following evaluation. Boxplots of annual ammonia concentrations for samples collected intermittently during water years 1979-90 for Sparks (fig. 23), intermittently during water years 1973-90 for Lockwood (fig. 24), and during water years 1973-90 for Nixon (fig. 25) indicate that ammonia concentrations appear

to have decreased at all three sites during the late 1980's. Flow-adjusted concentrations for Nixon decreased slightly during the study period. Ammonia removal from sewage effluent from TMWRF began in 1988 (Thomas Swan, TMWRF, oral commun., 1993).

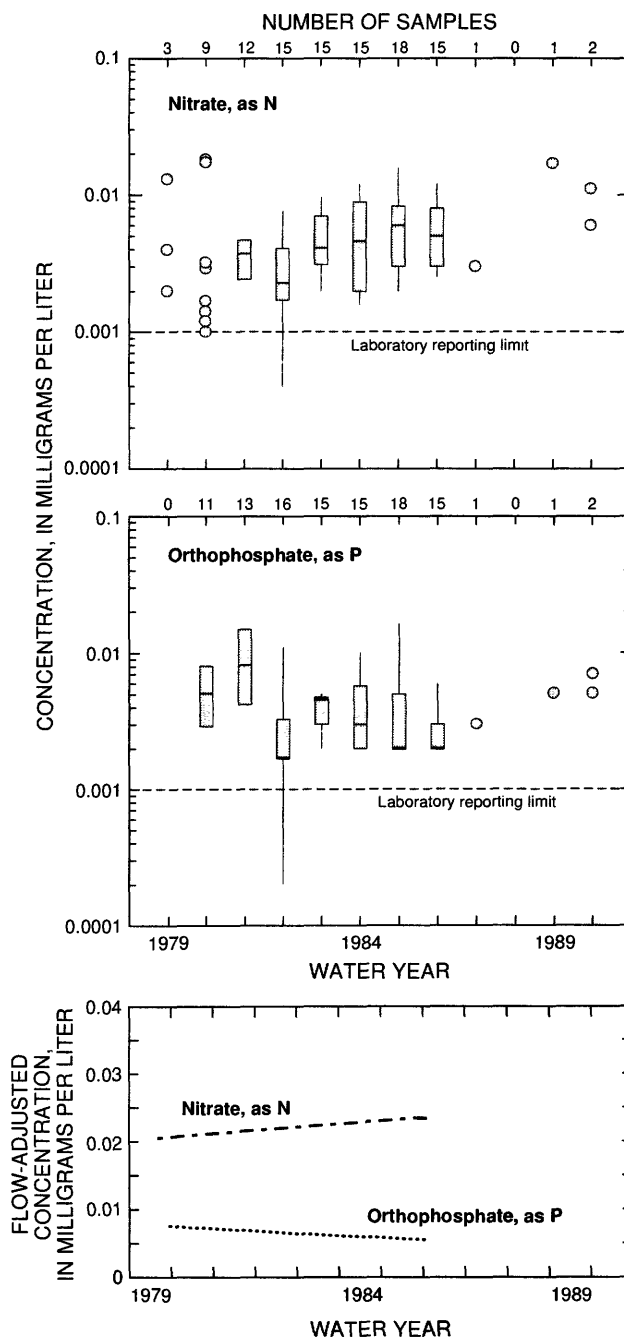


Figure 20. Yearly concentrations and study-period trends of nitrate and orthophosphate for Meeks Creek near Tahoe City, Calif., water year 1979 through April 1990.

The nitrate data are the most complete of all nutrient species analyzed in water samples collected during the study period. Only a slight study-period increase in flow-adjusted nitrate concentrations is apparent for data from Farad (fig. 22). Nitrate concentrations for

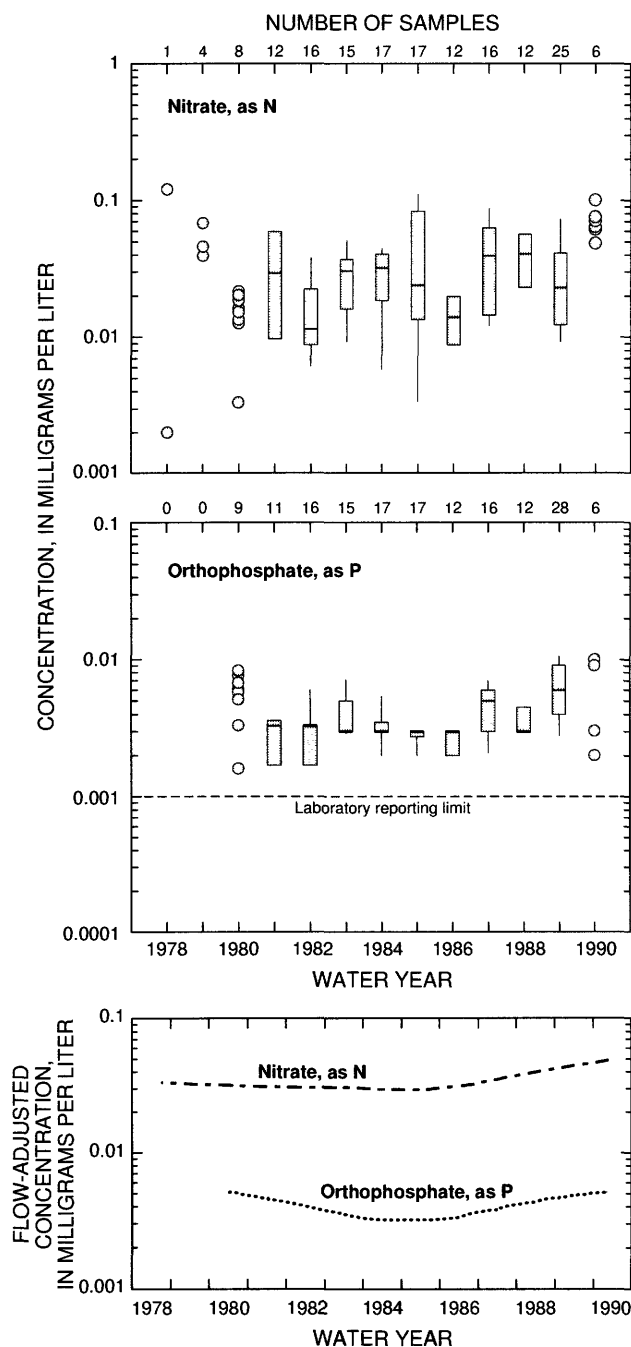


Figure 21. Yearly concentrations and study-period trends of nitrate and orthophosphate for Blackwood Creek near Tahoe City, Calif., water year 1978 through April 1990.

samples from Sparks have increased six-fold, possibly from increased urbanization (fig. 23). Nitrate concentrations at Lockwood have stayed about the same (fig. 24). Nitrate concentrations at Nixon have nearly doubled from water years 1973 through 1989; but few samples have been collected since 1987 (fig. 25).

The phosphorus data base has the same limitations as the nitrogen data base: only a few samples were analyzed and data collection was intermittent. Data for total-phosphorus concentrations were used only for Third and Incline Creeks because of the limitation imposed by different methods of sampling. Boxplots of annual total-phosphorus concentrations in samples collected from Third and Incline Creeks are shown in figure 26. At the Incline Creek site, the flow-adjusted total-phosphorus

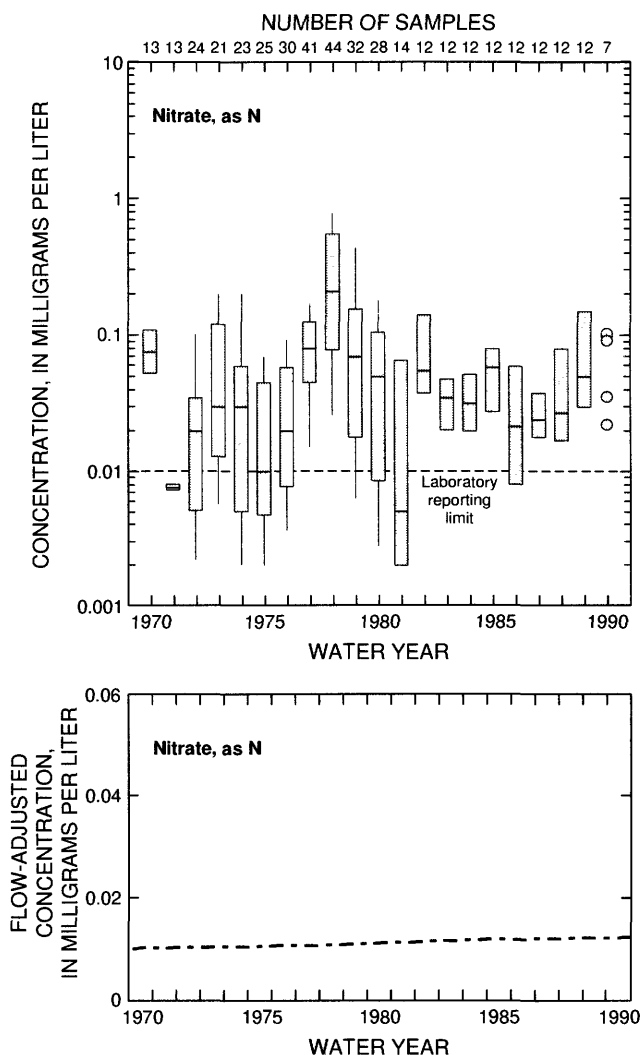


Figure 22. Yearly concentrations and study-period trends of nitrate for Truckee River at Farad, Calif., water year 1970 through April 1990.

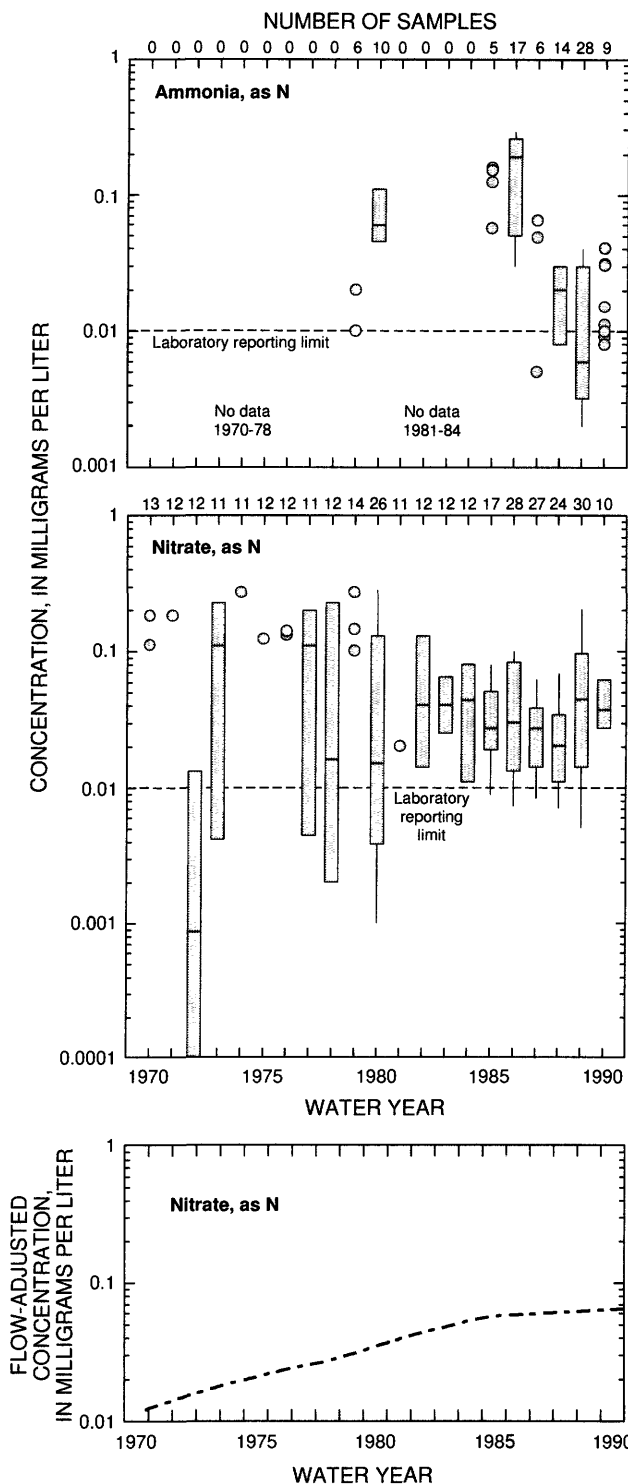


Figure 23. Yearly concentrations and study-period trends of ammonia and nitrate for Truckee River near Sparks, Nev., intermittent samples, water year 1970 through April 1990.

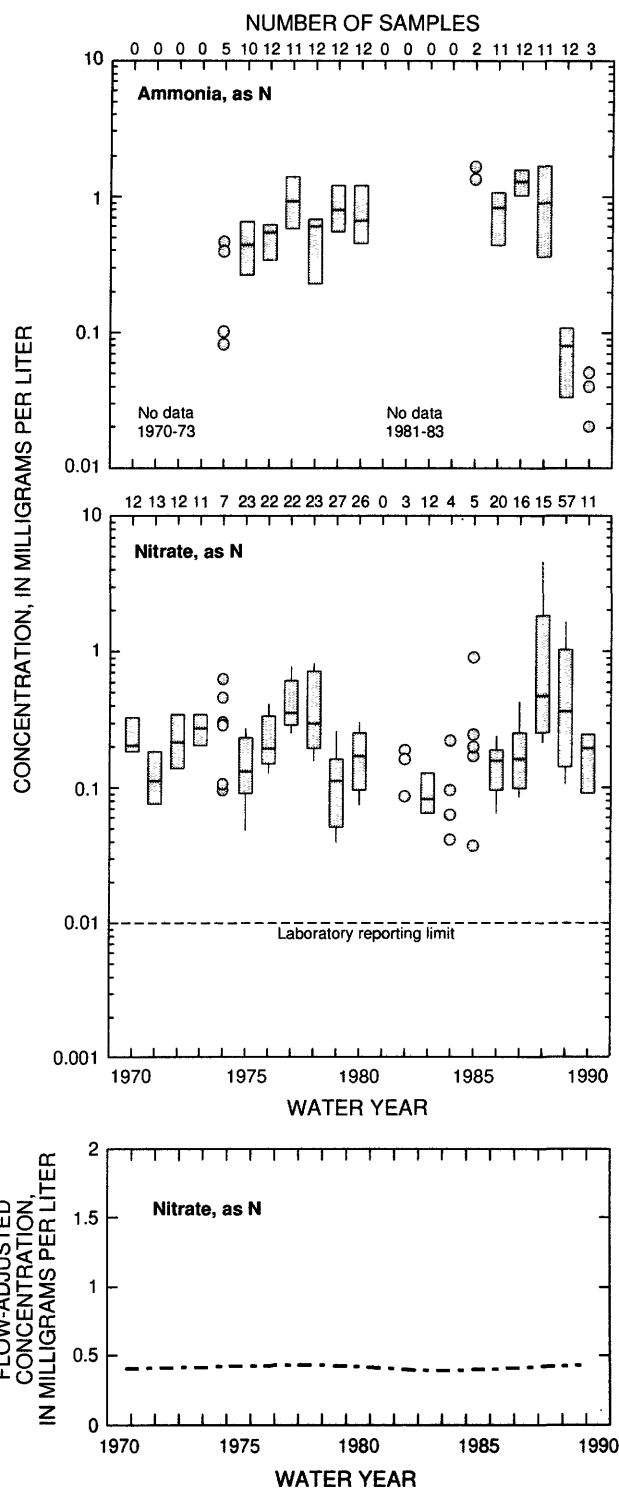


Figure 24. Yearly concentrations and study-period trends of ammonia and nitrate for Truckee River at Lockwood, Nev., water year 1970 through December 1989.

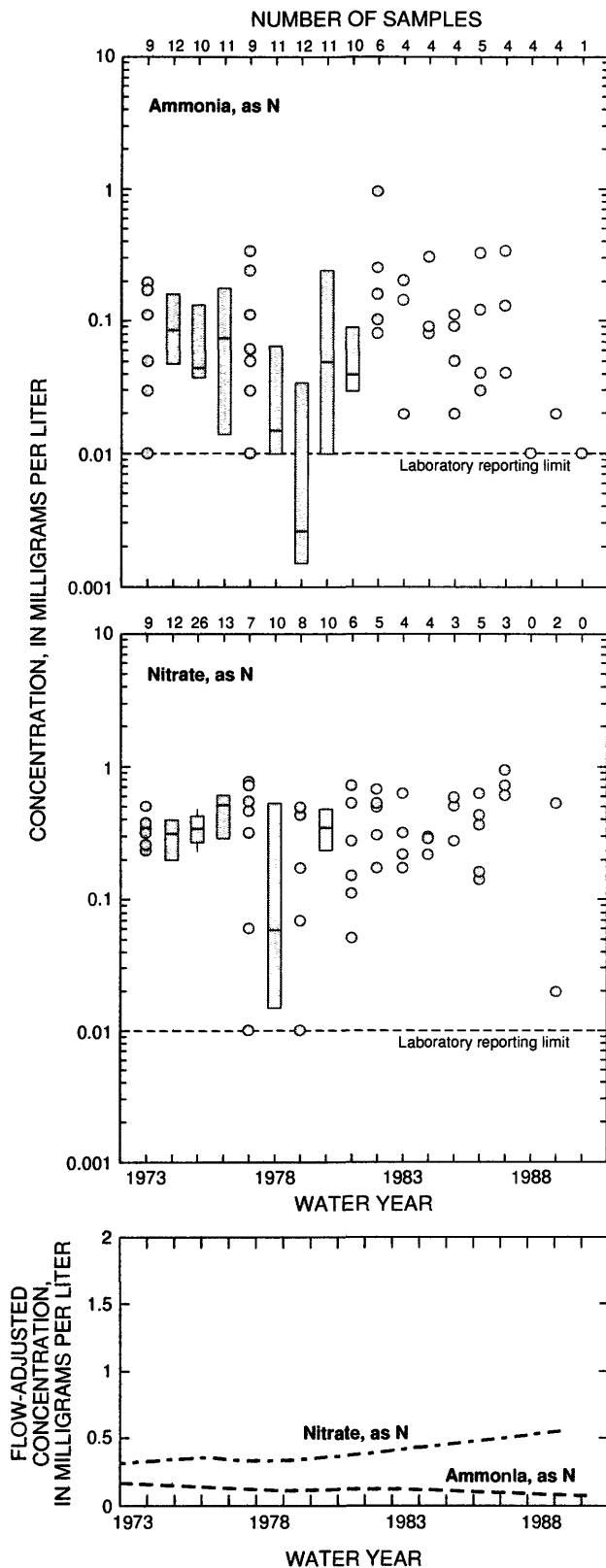


Figure 25. Yearly concentrations and study-period trends of ammonia and nitrate for Truckee River near Nixon, Nev., water year 1973 through March 1990.

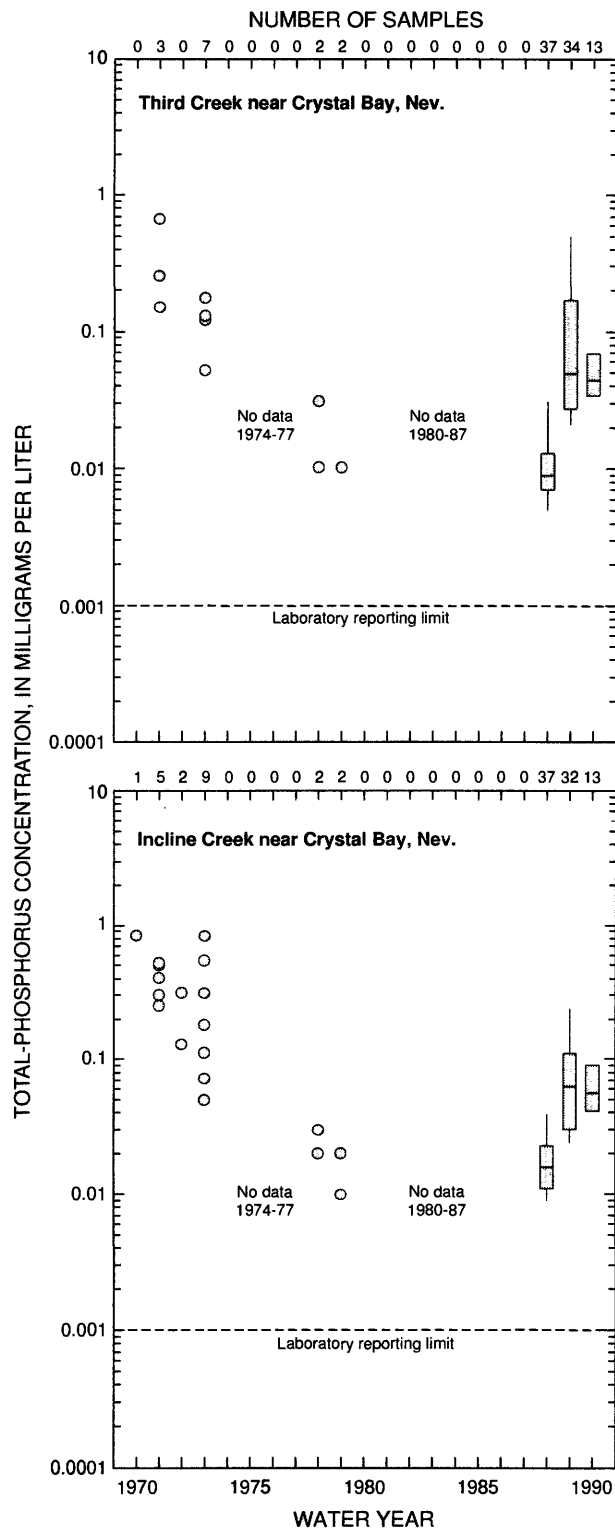


Figure 26. Yearly concentrations of total phosphorus for Third Creek near Crystal Bay, Nev., and Incline Creek near Crystal Bay, Nev., intermittent samples, water year 1970 through April 1990.

concentrations in samples collected during the early 1970's were significantly higher (p equals 0.01) than flow-adjusted concentrations in samples collected during the late 1980's; concentrations were not significantly different at Third Creek. Boxplots of annual orthophosphate concentrations for samples collected from Third and Incline Creeks are shown in figure 27. Flow-adjusted orthophosphate concentrations for samples from Third Creek were significantly higher (p less than 0.001) during the early 1970's; concentrations were not significantly different at Incline Creek. Orthophosphate concentrations (not flow-adjusted) in samples from Meeks Creek decreased between 1980 and 1985 (fig. 20). Samples were not collected before 1980 and few samples were collected after 1985. Orthophosphate concentrations were not flow-adjusted because a statistically significant relation with streamflow did not

exist. Flow-adjusted orthophosphate concentrations in samples from Blackwood Creek (fig. 21) have increased since water year 1986.

The trend analysis of total-phosphorus and orthophosphate concentrations along the Truckee River was hampered by large gaps in the data and too few samples. Increased sampling for total phosphorus by the TMWRF and Washoe County began in 1984 in an effort to refine an empirical water-quality model developed by USGS in the 1980's (Nowlin, 1987a). Depth-integration methods were used to collect samples in the centroid of flow. Study period changes in annual total-phosphorus and orthophosphate concentrations were examined for the Truckee River at Farad (fig. 28), near Sparks (fig. 29), at Lockwood (fig. 30), and near Nixon (fig. 31).

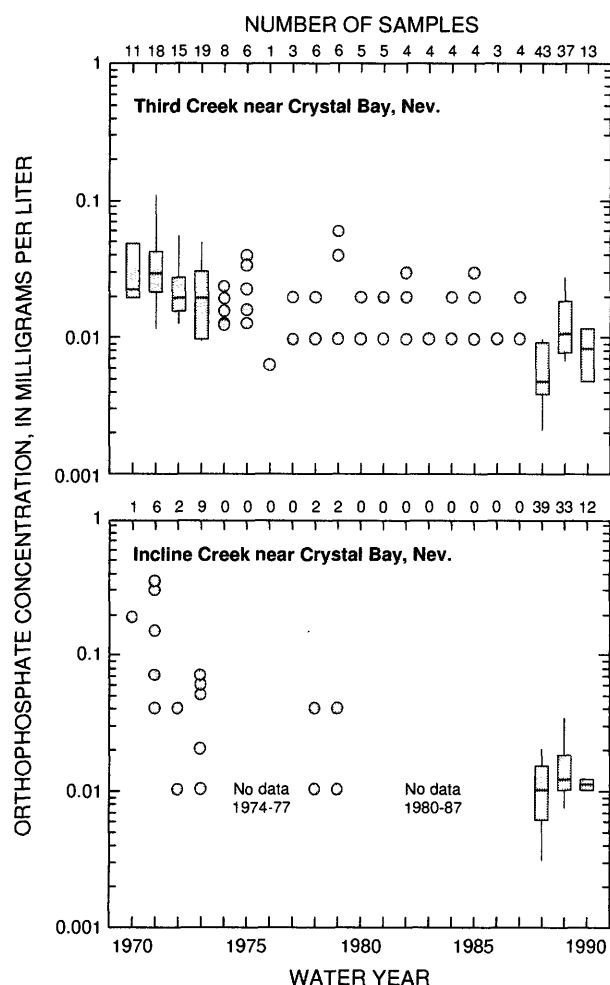


Figure 27. Yearly concentrations of orthophosphate for Third Creek near Crystal Bay, Nev., and Incline Creek near Crystal Bay, Nev., intermittent samples, water year 1970 through April 1990.

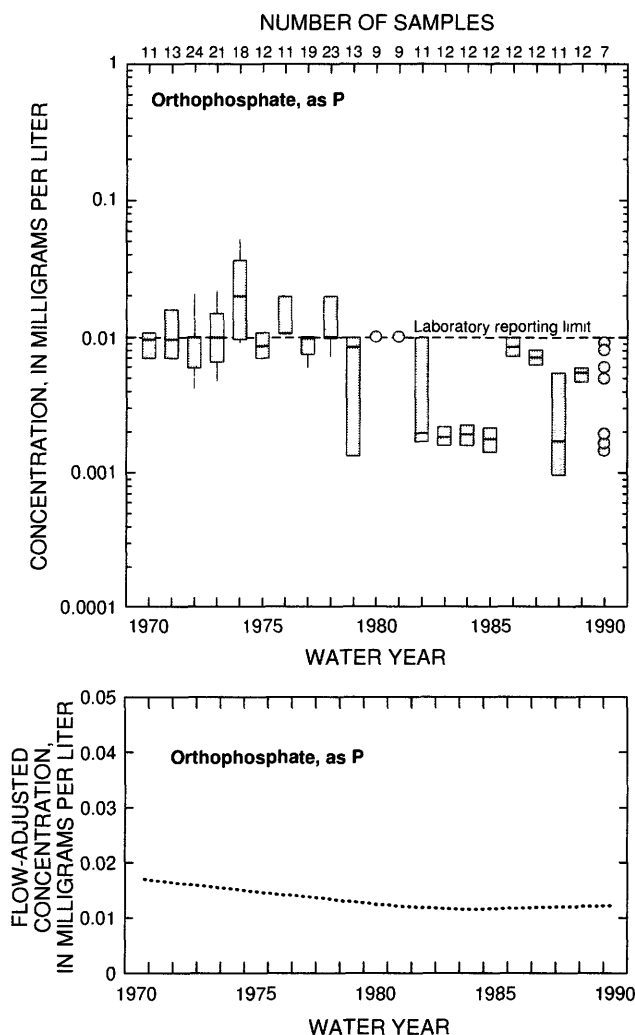


Figure 28. Yearly concentrations and study-period trend of orthophosphate for Truckee River at Farad, Calif., water year 1970 through April 1990.

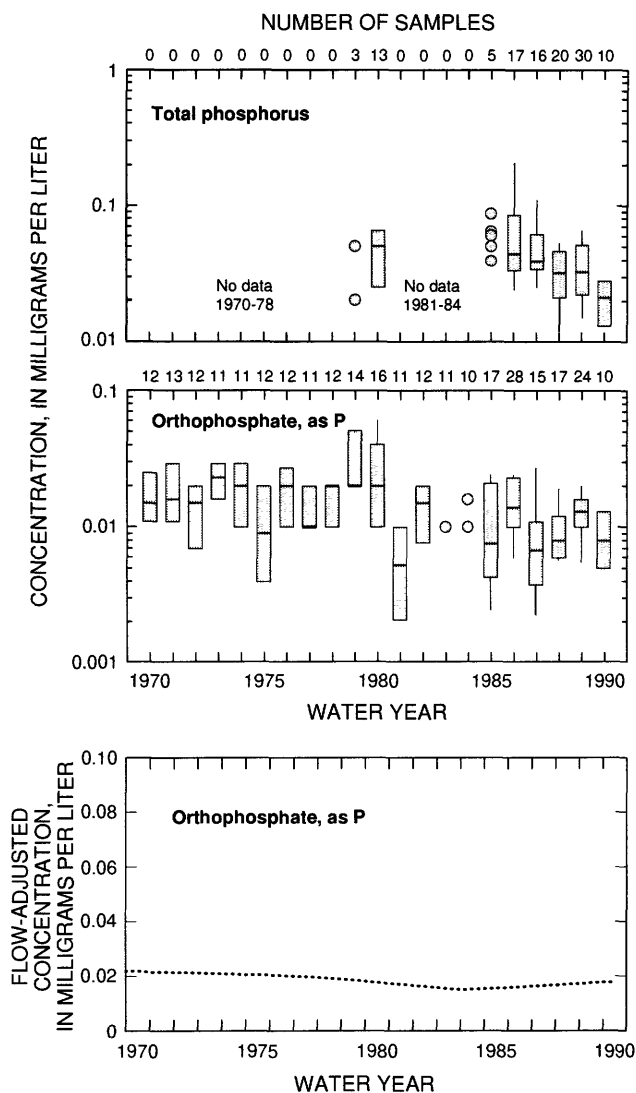


Figure 29. Yearly concentrations and study-period trends of total phosphorus and orthophosphate for Truckee River near Sparks, Nev., water year 1970 through April 1990.

Total-phosphorus concentrations near Sparks appear to have decreased during water years 1985 through April 1990 (fig. 29). The flow-adjusted trend for total phosphorus at Nixon shows a decrease of about 0.15 mg/L during water years 1980-88 (fig. 31). Flow-adjusted orthophosphate concentrations at Farad decreased during water years 1970-84, but have remained constant since water year 1985 (fig. 28). Flow-adjusted orthophosphate concentrations at Sparks decreased slightly during water years 1970-84, but have increased since 1984 (fig. 29). Insufficient

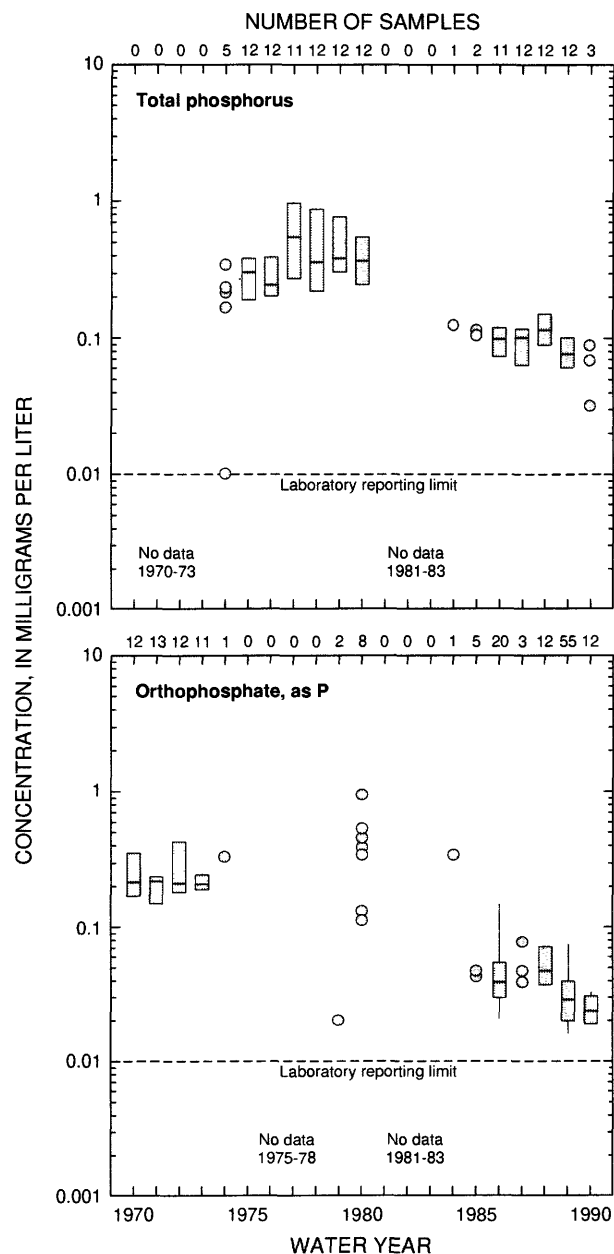


Figure 30. Yearly concentrations of total phosphorus and orthophosphate for Truckee River at Lockwood, Nev., intermittent samples, water year 1970 through December 1989.

data for Lockwood (fig. 30) precluded trend analysis. Flow-adjusted orthophosphate concentrations at Nixon decreased by 0.15 mg/L from 1980-88. In the mid-1980's, the TMWRF began removing phosphorus from effluent.

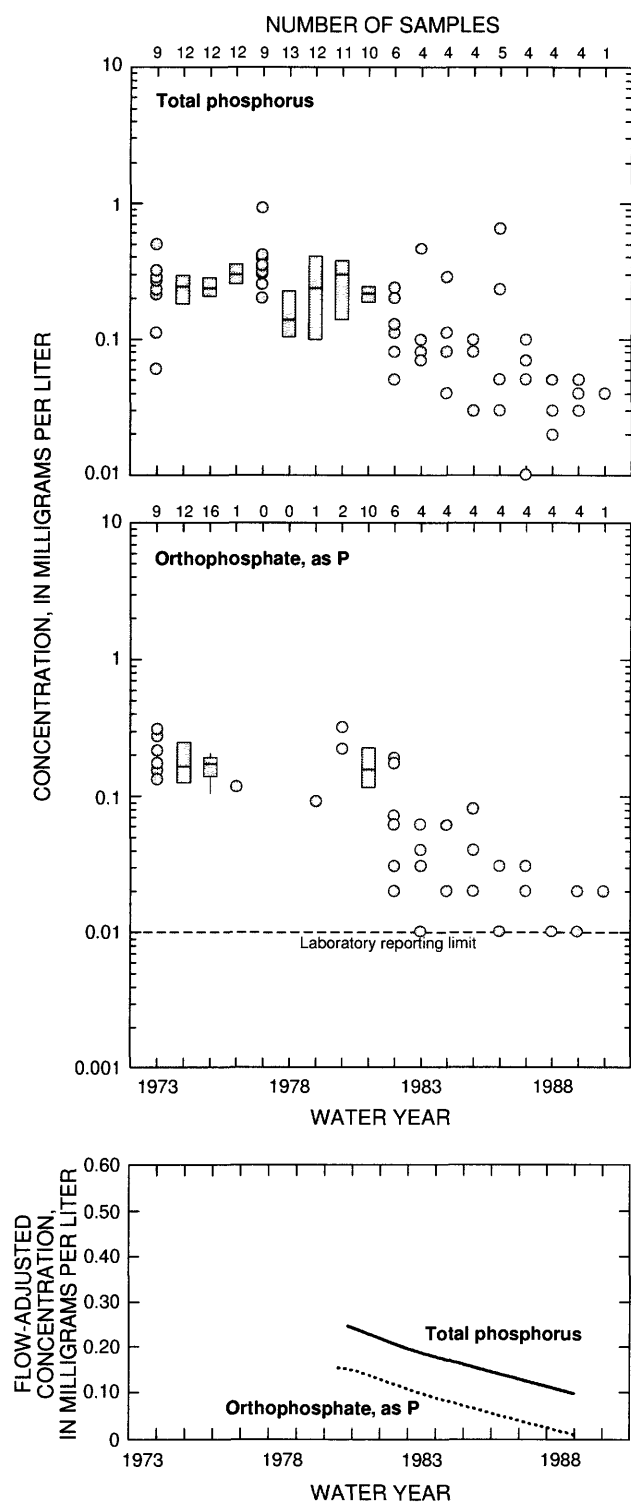


Figure 31. Yearly concentrations and study-period trends of total phosphorus and orthophosphate for Truckee River near Nixon, Nev., water year 1973 through December 1989.

Annual Trends

Data limitations also hindered the analysis of seasonal differences in nitrogen concentrations. Ammonia concentrations for samples from Third and Incline Creeks were evaluated for annual variations. The flow-adjusted concentrations of ammonia in samples from Third (fig. 32) and Incline (fig. 33) Creeks have no apparent annual trend. Nitrate concentrations in samples from Third and Incline Creeks peak in the late winter and early spring and are lowest in the late spring. Flow-adjusted concentrations differed by less than 0.01 mg/L as N. This is not enough to differentiate between analytical variability and biological activity. Flow-adjusted nitrate concentrations for Meeks Creek peak in the late winter and early spring (fig. 34); but the difference in concentrations was slight. Flow-adjusted nitrate concentrations for Blackwood Creek tended to be highest in early spring, and were lowest in late spring and early summer; however, the data were limited (fig. 34). This trend may be caused by biological activity, perhaps diatom blooms.

Most of the nitrogen species data for the Truckee River, when arranged in monthly boxplots, show differences in seasonal concentrations (figs. 35-38). Annual trends in flow-adjusted concentrations of some nitrogen species were seen at all four sites on the Truckee River (Farad, Sparks, Lockwood, and Nixon). Flow-adjusted nitrate concentrations at Farad were highest during the winter, probably because of reduced biological activity (fig. 35). Flow-adjusted ammonia concentrations showed no change on an annual scale at the Sparks site (fig. 36). Flow-adjusted nitrate concentrations were highest during the winter and lowest during the summer, probably a result of uptake by algae and aquatic macrophytes. Flow-adjusted total-nitrogen, ammonia, and nitrate concentrations at Lockwood are lowest in spring and highest in summer, possibly due to dominance of TMWRF effluent during low-flow periods (fig. 37). At the site near Nixon (fig. 38), the flow-adjusted trend showed that concentrations of total nitrogen, ammonia, and nitrate species generally were highest in winter and lowest in summer, probably because of uptake by algae and aquatic macrophytes. Nonparametric correlation showed significant monthly differences in flow-adjusted total-nitrogen (p less than 0.002), ammonia (p less than 0.001), and nitrate (p equals 0.011) concentrations.

Data limitations also hindered the evaluation of annual differences in phosphorus concentrations in the Lake Tahoe Basin. Boxplots of monthly total-phosphorus and orthophosphate concentrations for Third and Incline

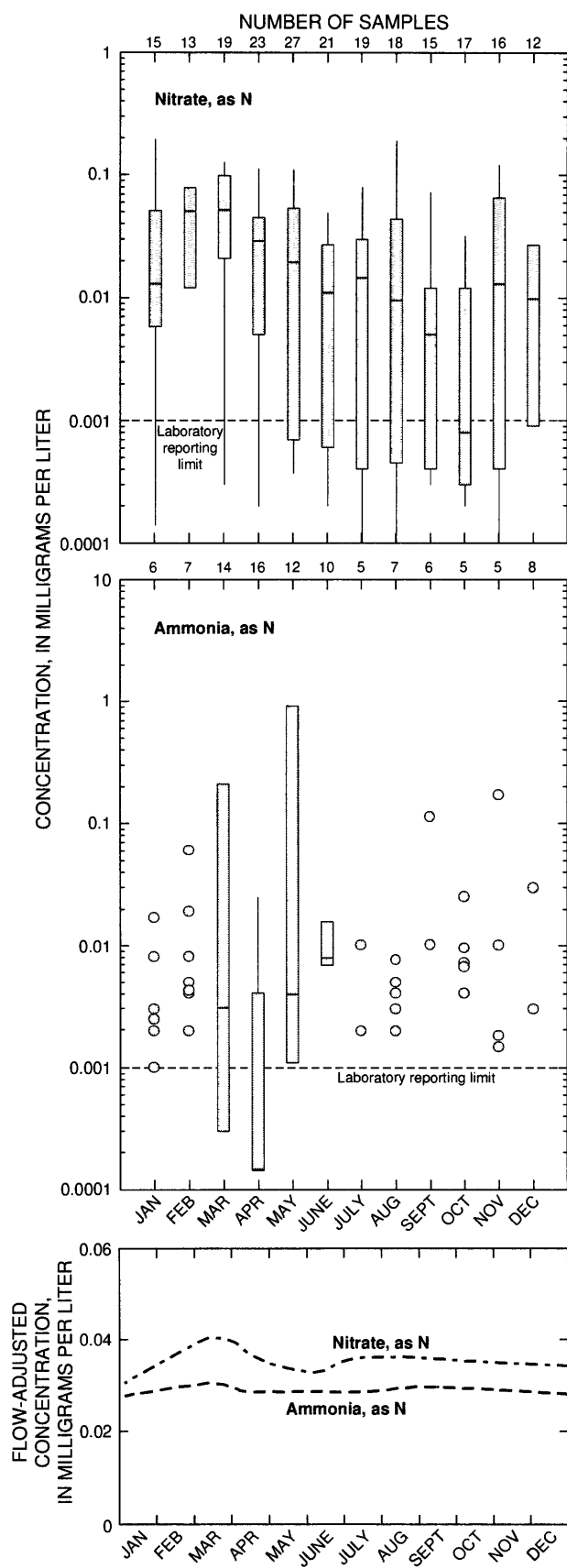


Figure 32. Monthly concentrations and annual trends of nitrate and ammonia for Third Creek near Crystal Bay, Nev., intermittent samples, water year 1970 through April 1990.

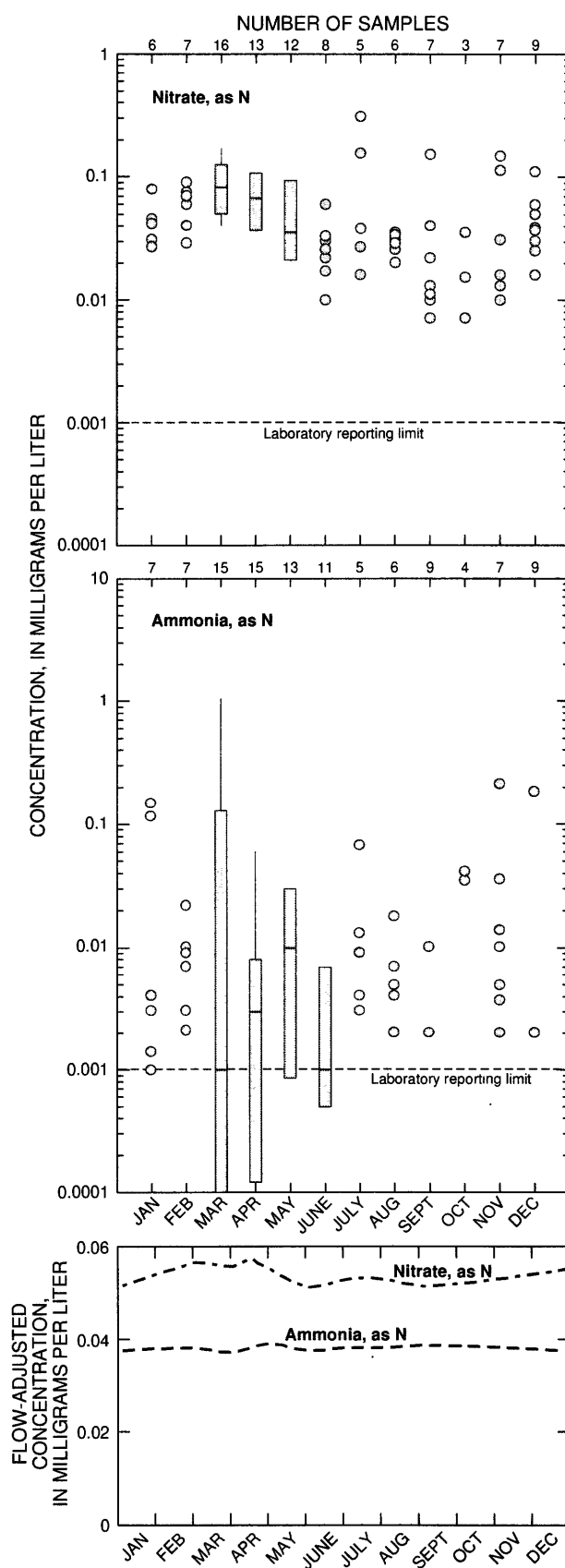


Figure 33. Monthly concentrations and annual trends of nitrate and ammonia for Incline Creek near Crystal Bay, Nev., intermittent samples, water year 1970 through April 1990.

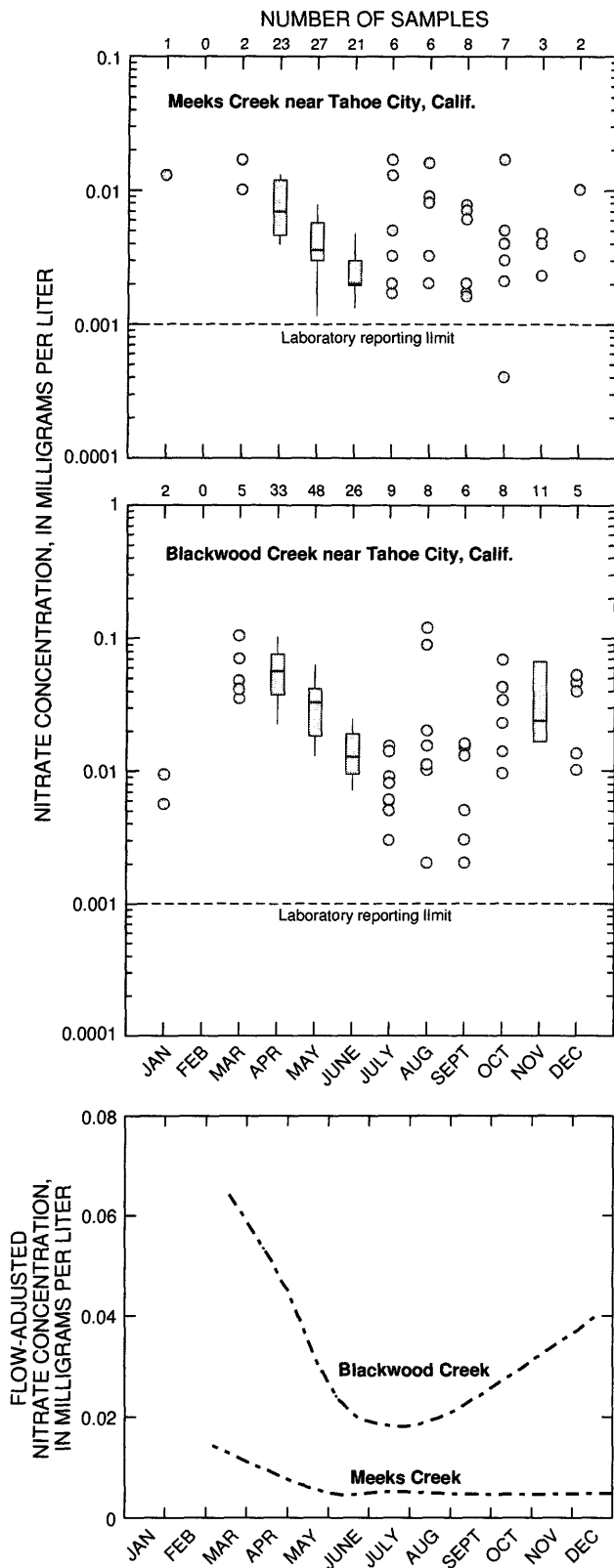


Figure 34. Monthly concentrations and annual trend of nitrate for Meeks Creek near Tahoe City, Calif., water year 1979 through April 1990, and Blackwood Creek near Tahoe City, Calif., water year 1978 through April 1990.

Creeks are shown in figures 39 and 40, respectively. Both streams had flow-adjusted total-phosphorus concentrations that were highest in late winter and lowest in late spring. No annual trends were observed in flow-adjusted orthophosphate concentrations for Third and Incline Creeks. Monthly boxplots and annual trends of orthophosphate concentrations for Meeks and Blackwood Creeks are shown in figure 41. Orthophosphate concentrations in Meeks Creek tend to be lowest in mid-spring and highest in autumn. Orthophosphate concentrations in Blackwood Creek tend to be lowest in late winter and early spring and highest in autumn (fig. 41A). These orthophosphate minima correspond to spring time diatom blooms that are common in streams (Hynes, 1970).

The annual distribution of total-phosphorus and orthophosphate concentrations for Truckee River sites, shown by monthly boxplots (figs. 42-45), indicates seasonal differences in concentrations. At some sites, an analysis of annual trends in flow-adjusted concentrations suggested that seasonal differences in total-phosphorus and orthophosphate concentrations could be a result of biological activity. However, seasonal differences in phosphorus concentrations probably were caused by streamflow differences at other sites. For instance, the absence of seasonal variability in flow-adjusted concentrations indicates that any variability in phosphorus concentrations observed in monthly boxplots is because of streamflow variability.

Trends for total-phosphorus concentrations are similar at Farad and Sparks. At these sites, flow-adjusted total-phosphorus concentrations are highest during summer (figs. 42 and 43). These total-phosphorus peaks probably were caused by high sediment loads entering the Truckee River from thunderstorm runoff. The average number of days with thunderstorm activity is between 10 and 15, primarily between May and July (Houghton and others, 1975, p. 50). At Sparks, the annual trend in flow-adjusted orthophosphate concentrations was similar to that of total phosphorus.

The highest concentrations of total phosphorus occur during the summer at Lockwood and during the winter at Nixon (figs. 44 and 45). The trend in flow-adjusted orthophosphate concentrations at Nixon is nearly identical to that of total phosphorus. High concentrations of phosphorus species at Lockwood during the summer may be due to the dominance of TMWRF effluent during this low-flow period.

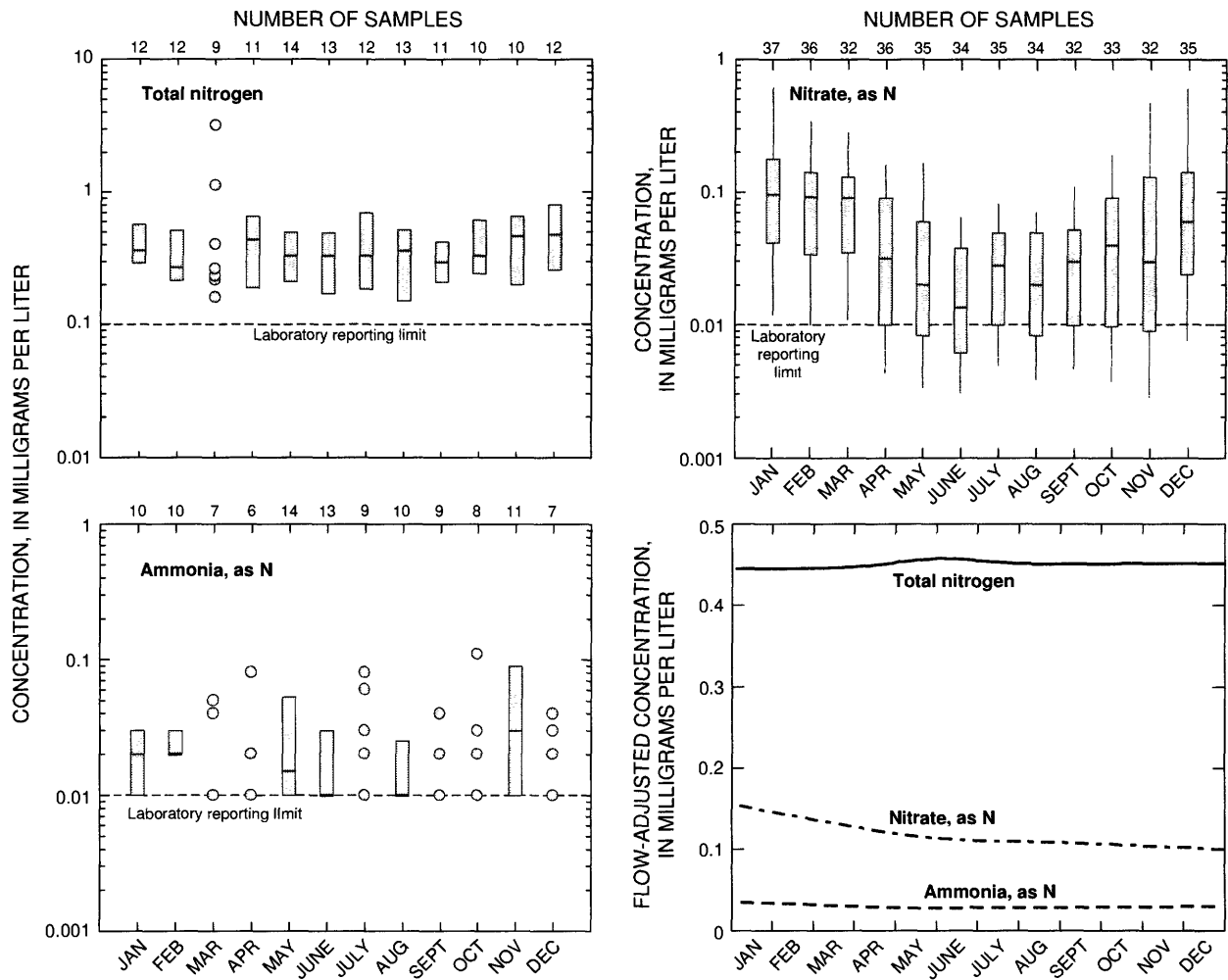


Figure 35. Monthly concentrations and annual trends of total nitrogen, ammonia, and nitrate for Truckee River at Farad, Calif., water year 1970 through April 1990.

Nutrient Concentrations and Streamflow

The relation between nutrient concentration and streamflow for selected sites was determined by comparing concentrations to percentiles of daily mean streamflow for the study period. Using streamflow percentiles standardized the flow regime at each site and allowed comparisons among sites. Values of individual samples for each nutrient concentration were plotted against an associated percentile of streamflow. From this scatterplot, LOWESS curves were constructed to show the trend in nutrient concentrations as streamflow increases.

In the Lake Tahoe Basin, total nitrogen was not evaluated because total nitrogen was only sporadically analyzed in water samples. Nutrient data from Martis Creek were not evaluated because no streamflow data were available. Blackwood, Third, and Incline Creeks all showed

changes in ammonia and nitrate concentrations as daily mean streamflow changed (fig. 46). As streamflow in Third Creek increased from the 30th to the 70th percentile, ammonia concentrations increased to their peak and then declined. This response suggests a "flush" of ammonia. In contrast, ammonia concentrations in Incline Creek began to increase at about the 70th percentile of streamflow and then stabilized at a concentration about nine times higher than concentrations during the lowest 20th percentile of streamflow. Nitrate samples from Blackwood and Third Creeks showed a "flush" response similar to the ammonia response seen at Third Creek. Nitrate concentrations in Incline Creek were similar to ammonia; however, the increase beyond the 70th percentile of streamflow was not as great.

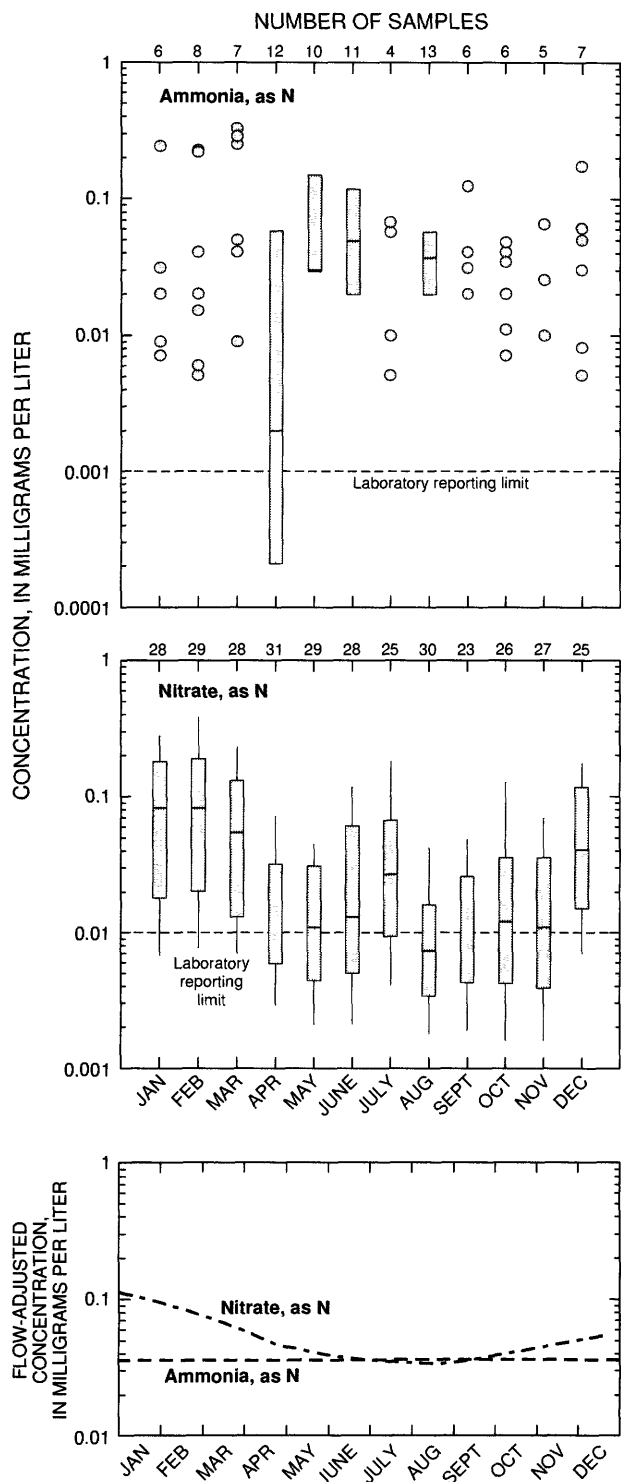


Figure 36. Monthly concentrations and annual trends of ammonia and nitrate for Truckee River near Sparks, Nev., water year 1970 through April 1990.

The relations of nutrient concentration to stream-flow percentiles were markedly different for the upstream site at Farad than for the downstream sites near Sparks and Nixon. At Farad, total-nitrogen and nitrate concentrations decreased as streamflow increased (fig. 47). These results suggest that the nutrient concentrations were diluted as streamflow increased. Some retention of total nitrogen in upstream reservoirs may create the appearance of dilution during increased streamflow. Ammonia concentrations at Farad remained relatively constant throughout the flow regime (fig. 47). In contrast, total-nitrogen and ammonia concentrations increased as streamflow increased near Sparks and Nixon (fig. 47). Nitrate concentrations near Sparks peaked when streamflow approached the 70th percentile. Nitrate concentrations near Nixon increased rapidly with increasing streamflow, peaked at about the 50th percentile, then decreased rapidly (fig. 47). These patterns suggest a "flush" of nitrate at both sites. The source of the nitrate near Sparks is uncertain, but may be urban and agricultural runoff. The nitrate source for the site near Nixon probably is treated sewage effluent from the TMWRF.

Total-phosphorus and orthophosphate concentrations in samples from Third Creek decreased slightly between about the 10th and 30th percentiles of streamflow. Total phosphorus then increased to about twice the concentration at the 10th percentile, and orthophosphate increased to about the same concentration as when streamflow was less than the 10th percentile (fig. 48). Total-phosphorus and orthophosphate concentrations at the Incline Creek site began to increase when streamflow exceeded about the 70th percentile (fig. 48). These two phosphorus species show a response similar to the observed response of ammonia and nitrate concentrations at Incline Creek. Orthophosphate concentrations from Blackwood Creek decreased slightly as streamflow increased (fig. 48). Although this suggests dilution of orthophosphate concentrations, the difference between the highest and lowest concentration ranged from 0.001 to 0.003 mg/L, and was within analytical uncertainty.

Little or no relation between total-phosphorus or orthophosphate concentrations and streamflow was observed for the Truckee River at the Farad or Sparks sites (fig. 49). Both total-phosphorus and

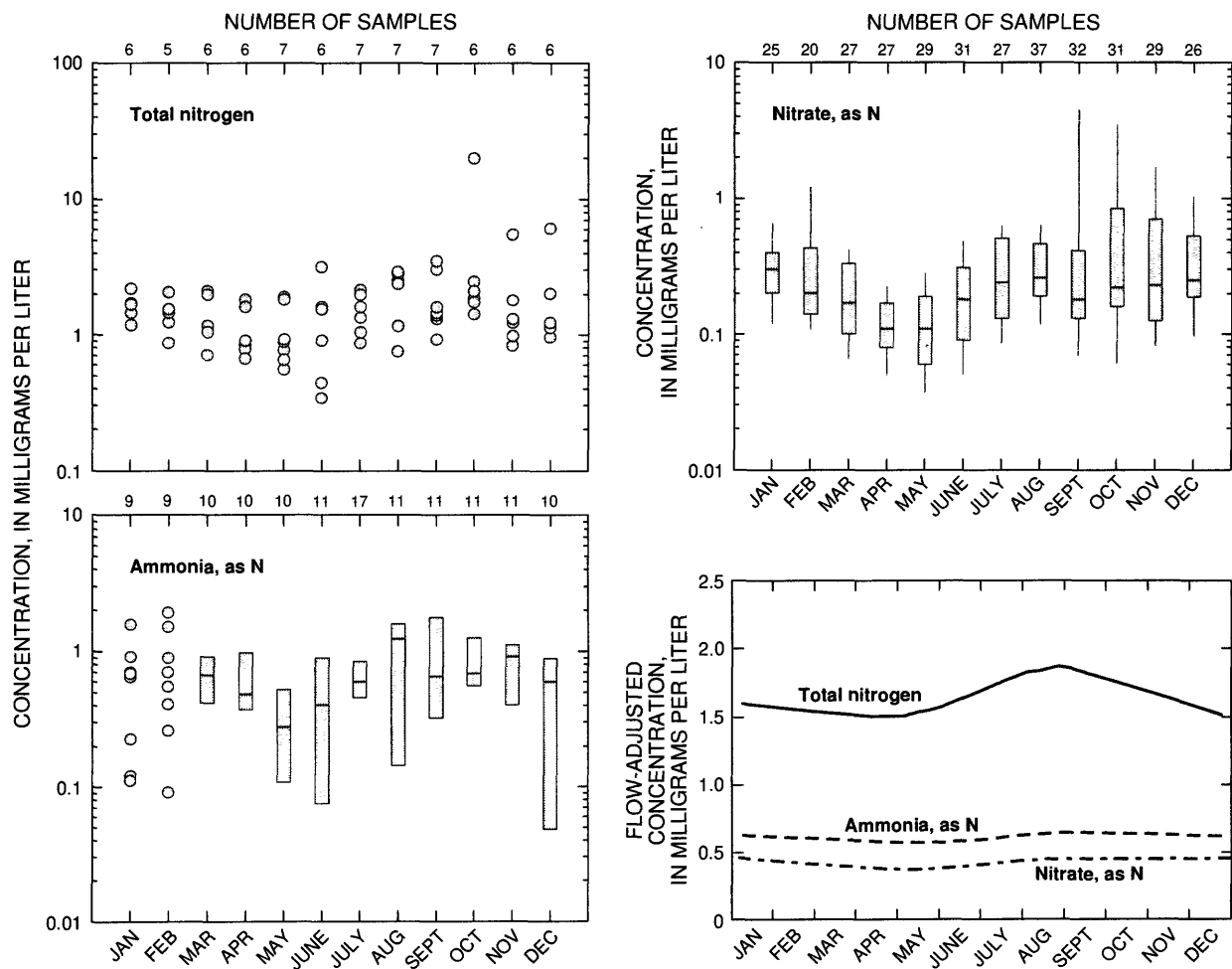


Figure 37. Monthly concentrations and annual trends of total nitrogen, ammonia, and nitrate for Truckee River at Lockwood, Nev., water year 1970 through April 1990.

orthophosphate concentrations peaked at about the 50th percentile of streamflow for Nixon (fig. 49). These responses probably are related to the discharge of treated sewage effluent from TMWRF for flows up to the 50th percentile and dilution from precipitation runoff during higher flows.

Nutrient Loads

Characterizing nutrient transport in the Lake Tahoe Basin was difficult because of the absence of long-term water-quality monitoring sites. Third Creek was the only stream with sufficient data for computing nutrient loads. Equations used to compute nutrient loads for Third Creek are given in table 3.

The mean annual total-nitrogen load for the 16 years of record during water years 1970-89 at Third Creek was about 6.5 tons (fig. 50). The monthly mean

total-nitrogen loads were highest in May and June and correspond to high streamflow caused by snowmelt runoff.

The mean annual total-phosphorus load for the 16 years of record during water years 1970-89 was 1.7 tons for Third Creek (fig. 50). Monthly mean total-phosphorus loads peaked in May and June as a result of higher streamflows caused by snowmelt runoff.

The transport of nutrients in the Truckee River system is exceedingly complex. The complexity is the result of regulation by impoundments, numerous diversions, return flows, and interbasin transfers of Truckee River water. A mass-balance approach to determine nitrogen and phosphorus loads is not feasible within the scope of this report because of the complex movement of water in the Truckee River Basin. Because of the lack of sufficient data, nitrogen and phosphorus loads are estimated only for the Truckee River near

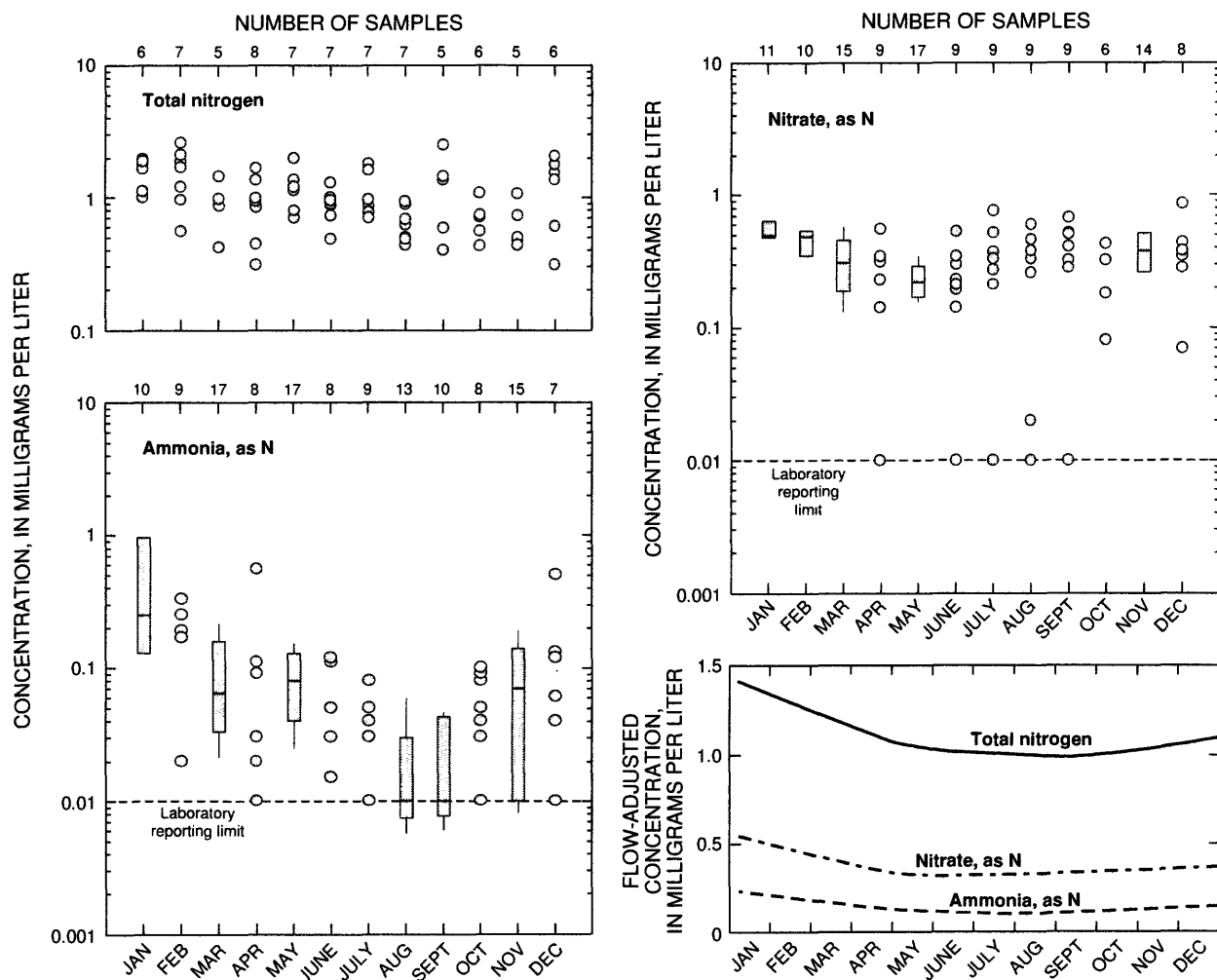


Figure 38. Monthly concentrations and annual trends of total nitrogen, ammonia, and nitrate for Truckee River near Nixon, Nev., water year 1973 through March 1990.

Nixon, which represents loads that enter Pyramid Lake. The mean annual total-nitrogen load for the study period was more than 900 tons near Nixon (fig. 51). Most of the annual total-nitrogen load was transported during January through June when streamflow was high (fig. 52).

The mean annual total-phosphorus load near Nixon was about 210 tons during the study period (fig. 51). Most of the total-phosphorus load was transported during January through June when streamflow was high (fig. 52).

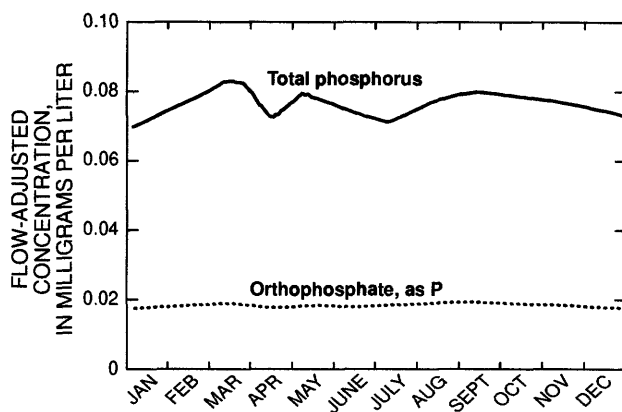
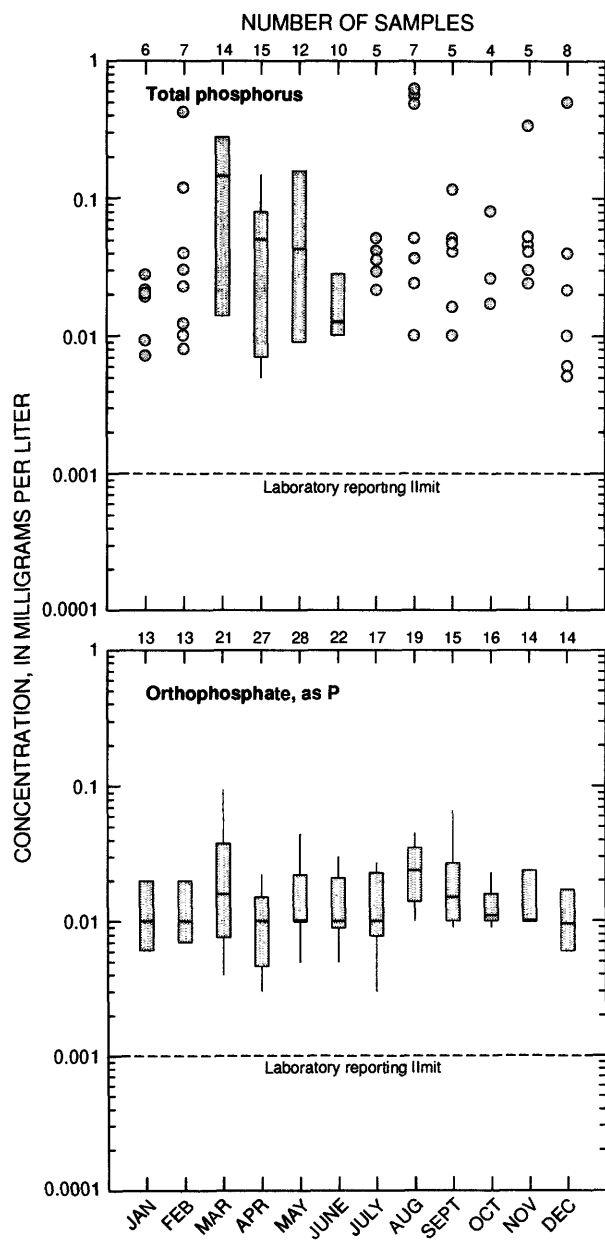


Figure 39. Monthly concentrations and annual trends of total phosphorus and orthophosphate for Third Creek near Crystal Bay, Nev., intermittent samples, water year 1970 through April 1990.

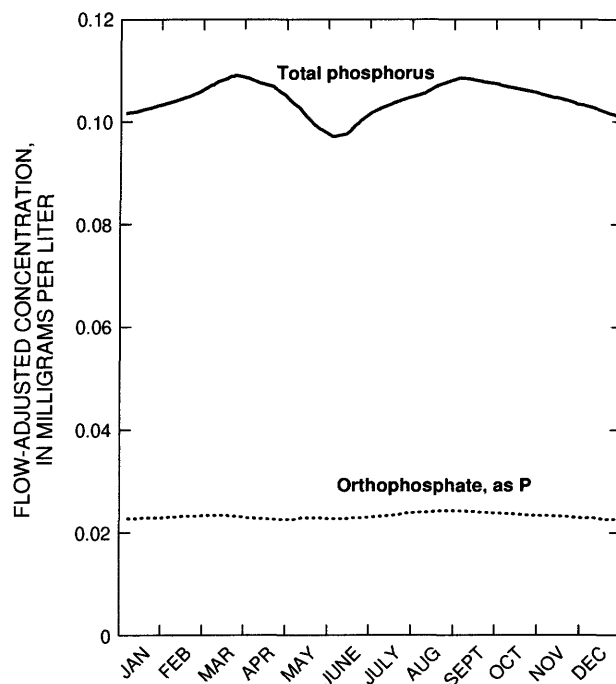
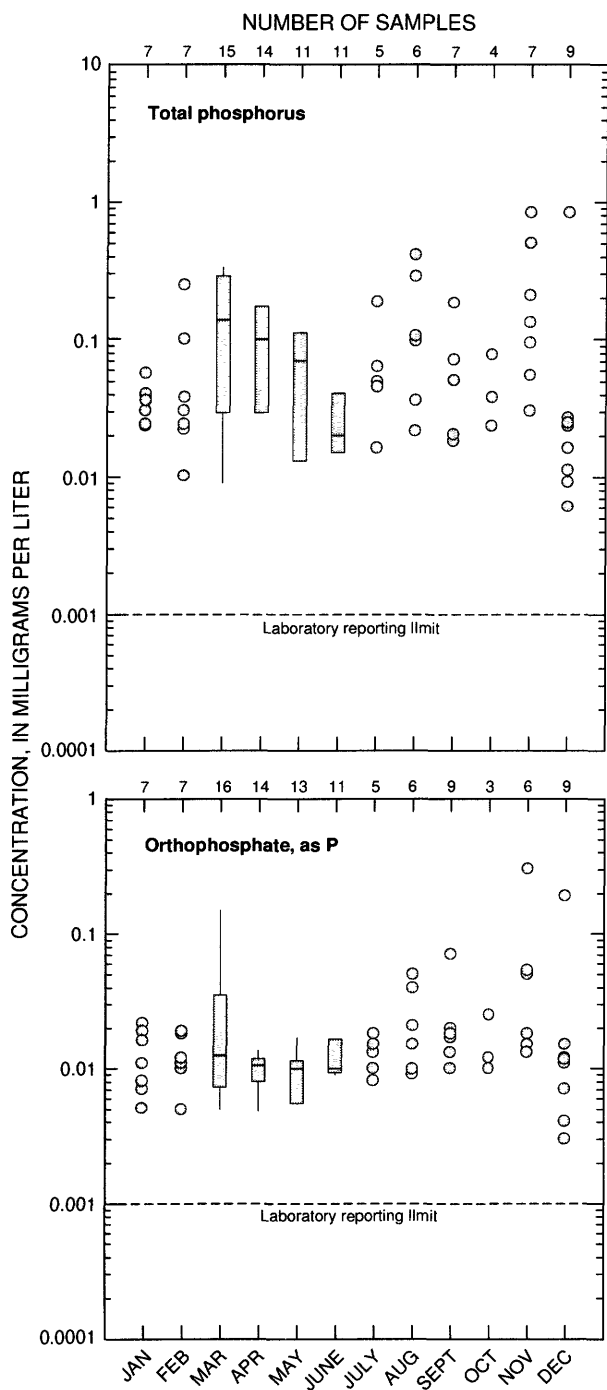


Figure 40. Monthly concentrations and annual trends of total phosphorus and orthophosphate for Incline Creek near Crystal Bay, Nev., intermittent samples, water year 1970 through April 1990.

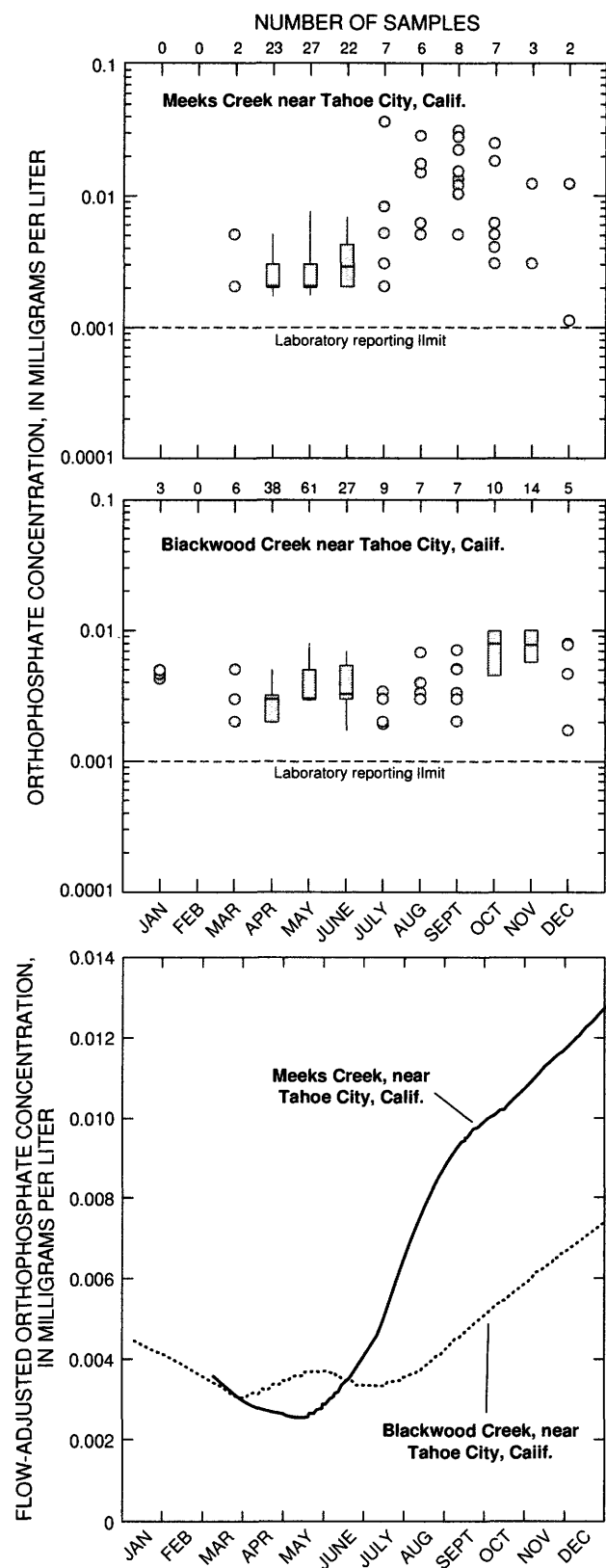


Figure 41. Monthly concentrations and annual trends of orthophosphate for Meeks Creek near Tahoe City, Calif., water year 1979 through April 1990, and Blackwood Creek near Tahoe City, Calif., water year 1978 through April 1990.

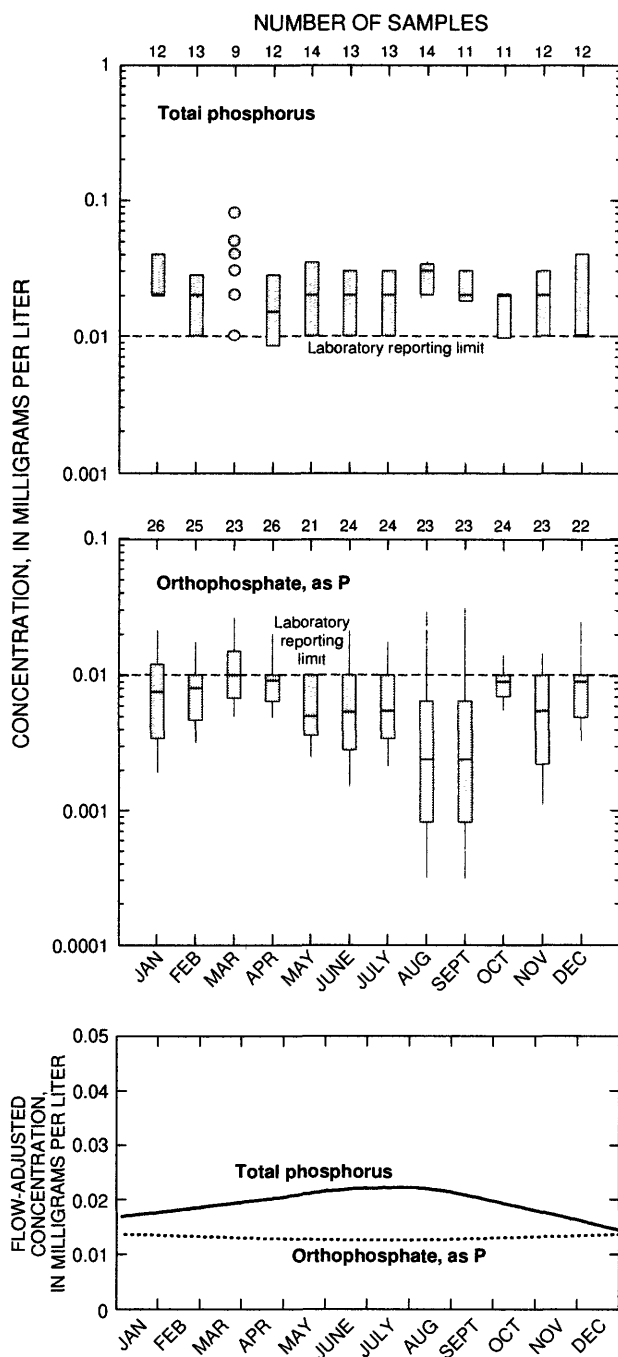


Figure 42. Monthly concentrations and annual trends of total phosphorus and orthophosphate for Truckee River at Farad, Calif., water year 1970 through April 1990.

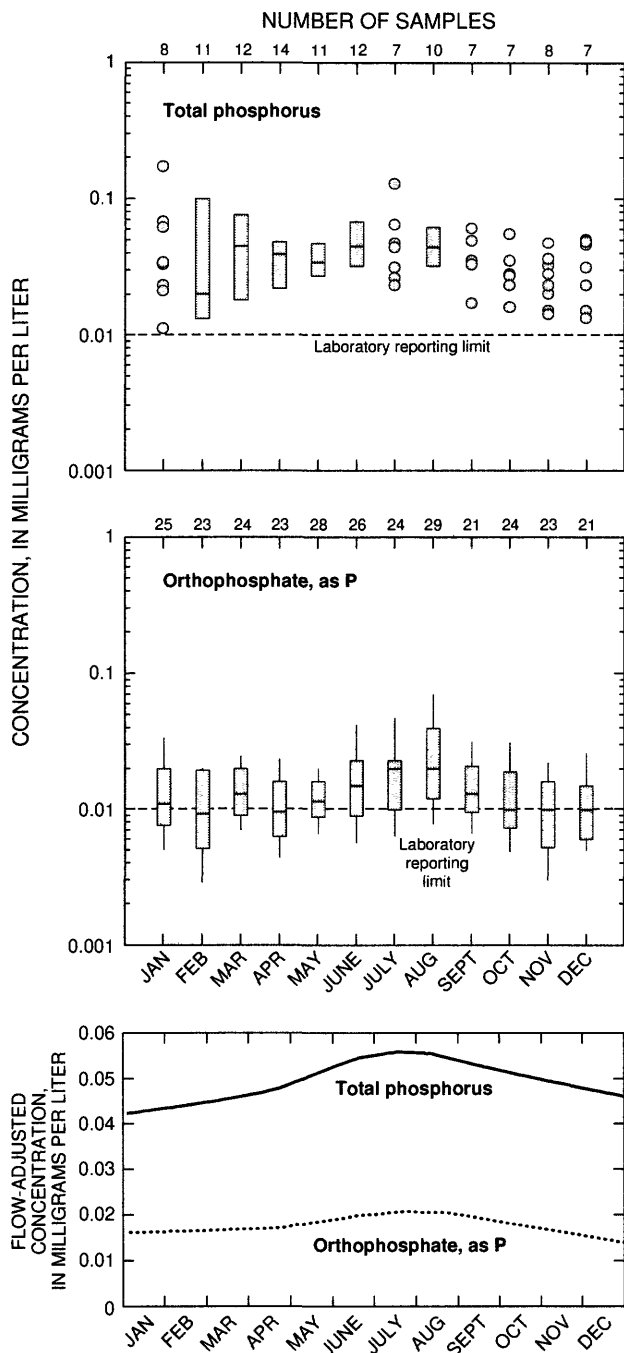


Figure 43. Monthly concentrations and annual trends of total phosphorus and orthophosphate for Truckee River near Sparks, Nev., water year 1970 through April 1990.

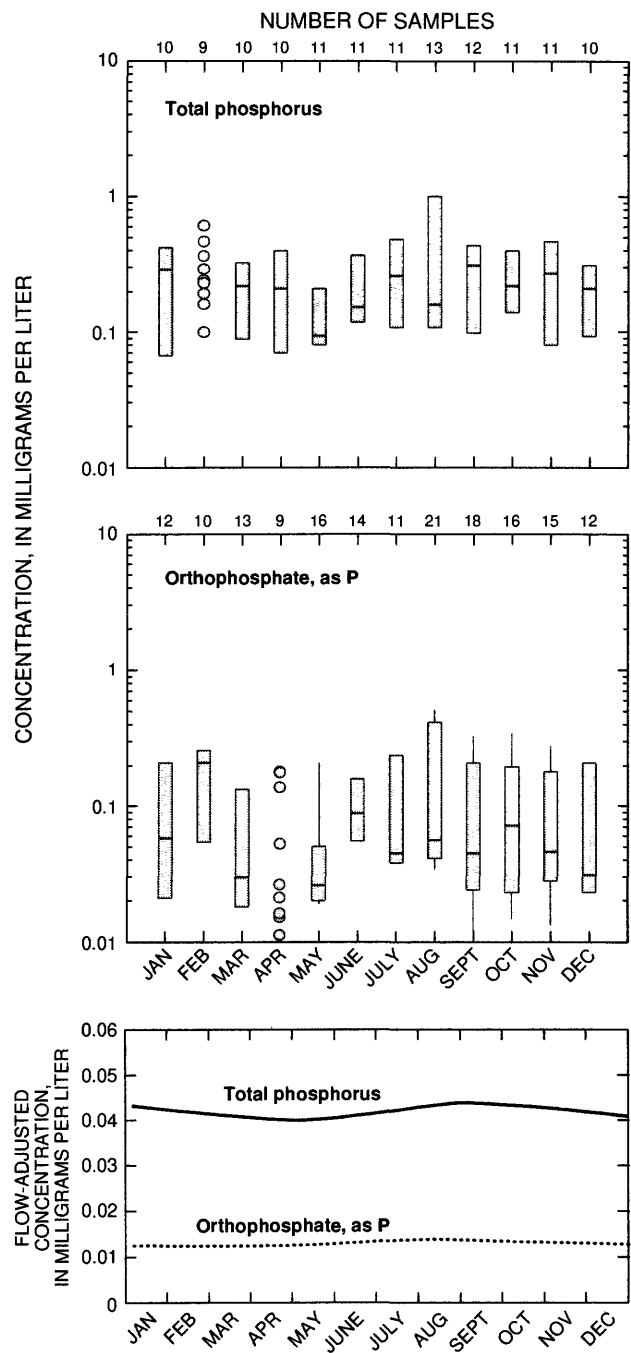


Figure 44. Monthly concentrations and annual trends of total phosphorus and orthophosphate for Truckee River at Lockwood, Nev., water year 1970 through December 1989.

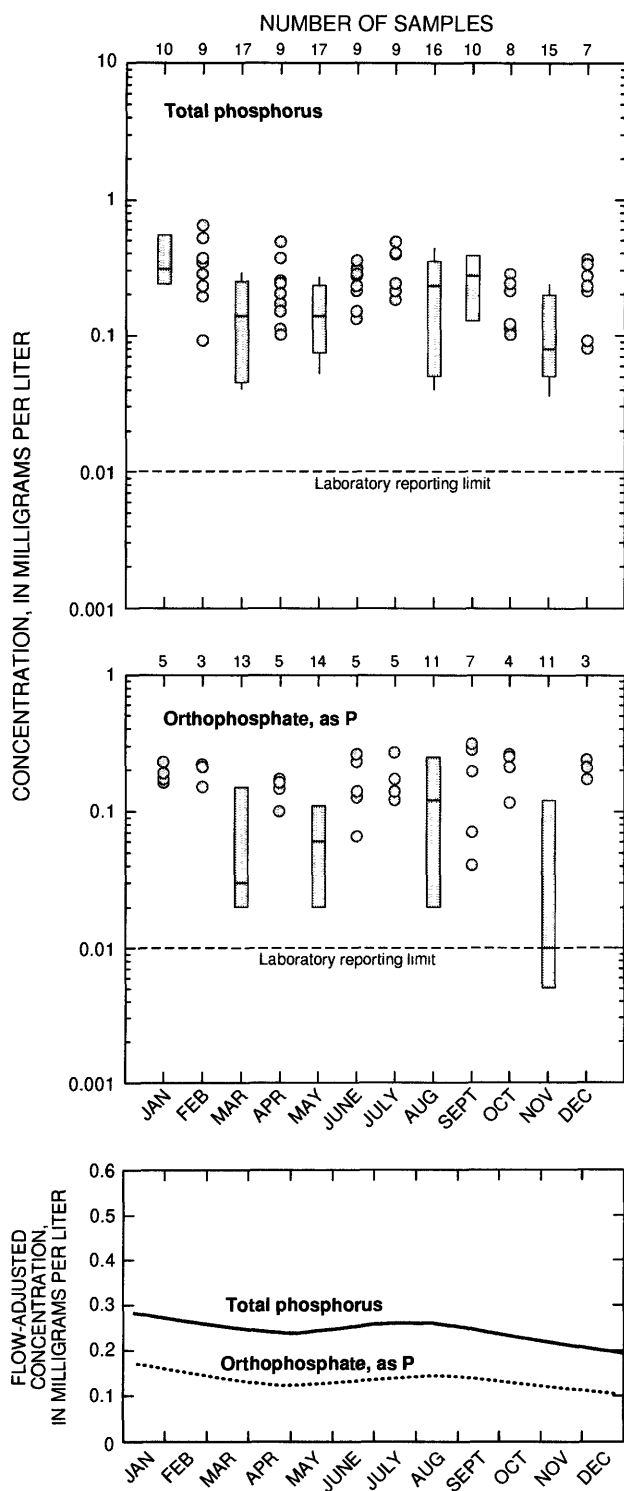


Figure 45. Monthly concentrations and annual trends of total phosphorus and orthophosphate for Truckee River near Nixon, Nev., water year 1973 through December 1989.

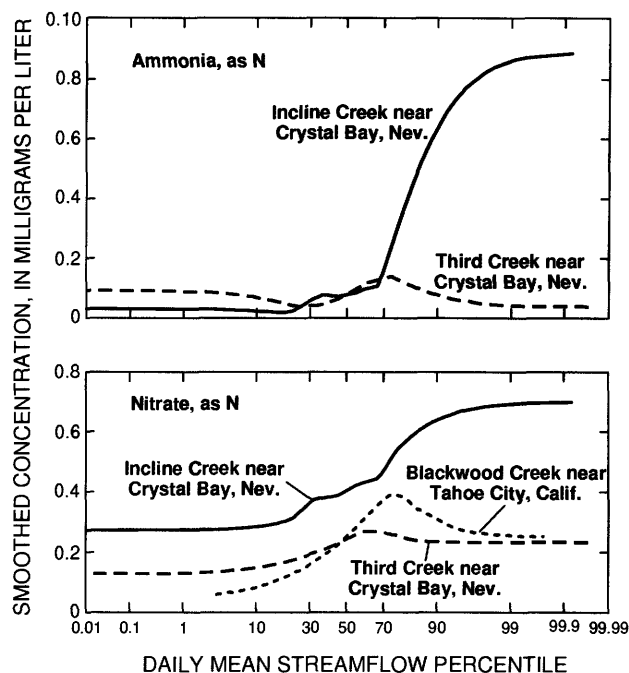


Figure 46. Relations of smoothed concentrations of ammonia and nitrate to streamflow percentiles for Blackwood Creek near Tahoe City, Calif., Third Creek near Crystal Bay, Nev., and Incline Creek near Crystal Bay, Nev., water year 1970 through April 1990. Daily mean streamflow values were converted to percentiles to facilitate comparison of relations among stations with different magnitudes of flow; 100th percentile corresponds to highest recorded daily mean flow and 50th percentile corresponds to median daily mean streamflow.

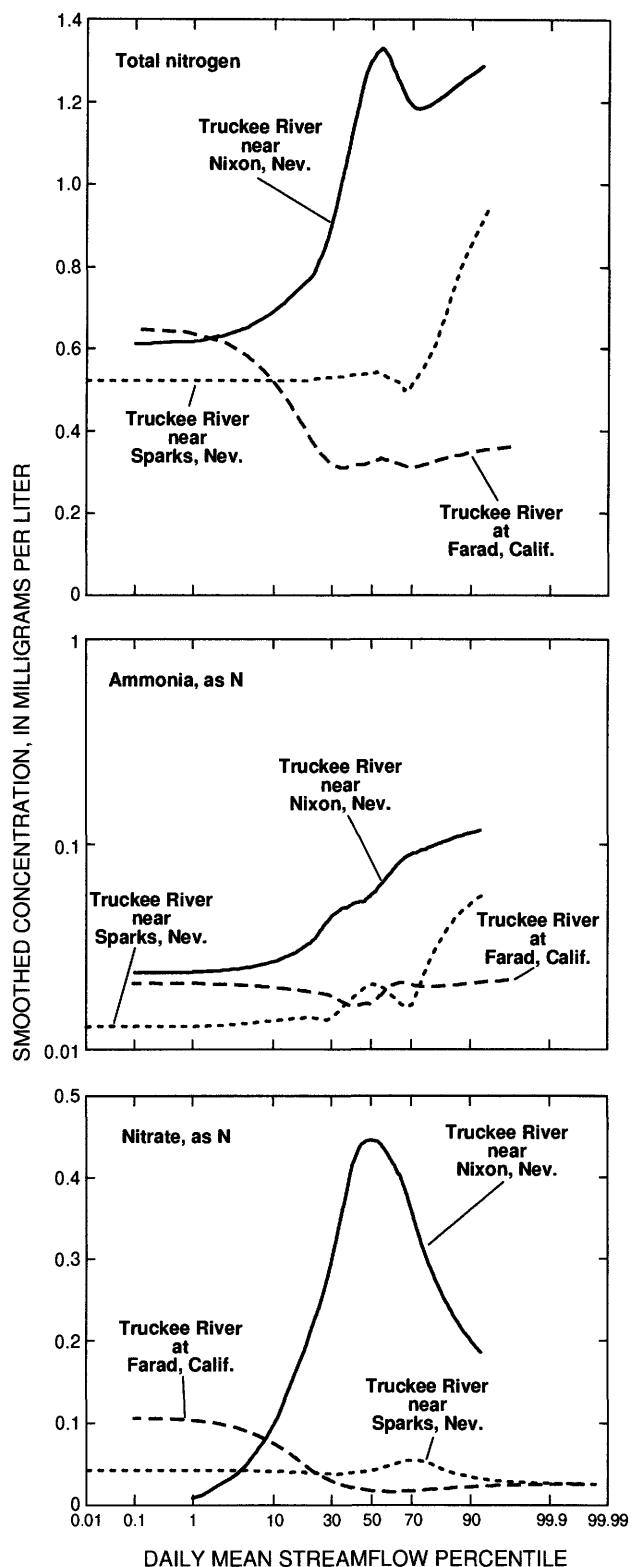


Figure 47. Relations of smoothed concentrations of total nitrogen, ammonia, and nitrate to streamflow percentiles for Truckee River at Farad, Calif., Truckee River near Sparks, Nev., and Truckee River near Nixon, Nev., water year 1970 through April 1990. Daily mean streamflow values were converted to percentiles to facilitate comparison of relations among stations with different magnitudes of flow; 100th percentile corresponds to highest recorded daily mean flow and 50th percentile corresponds to median daily mean streamflow.

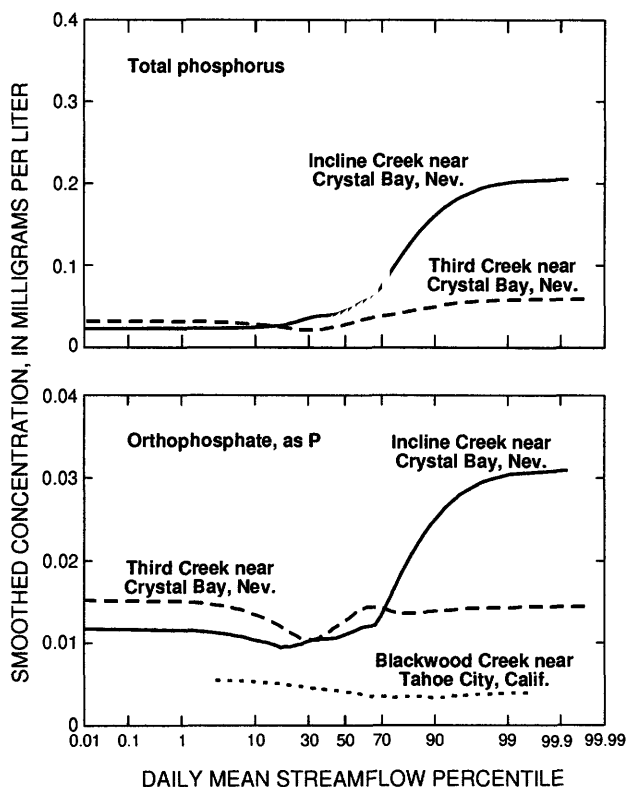


Figure 48. Relation of smoothed concentrations of total phosphorus and orthophosphate to streamflow percentiles for Blackwood Creek near Tahoe City, Calif., Third Creek near Crystal Bay, Nev., and Incline Creek near Crystal Bay, Nev., water year 1970 through April 1990. Daily mean streamflow values were converted to percentiles to facilitate comparison of relations among stations with different magnitudes of flow; 100th percentile corresponds to highest recorded daily mean flow and 50th percentile corresponds to median daily mean streamflow.

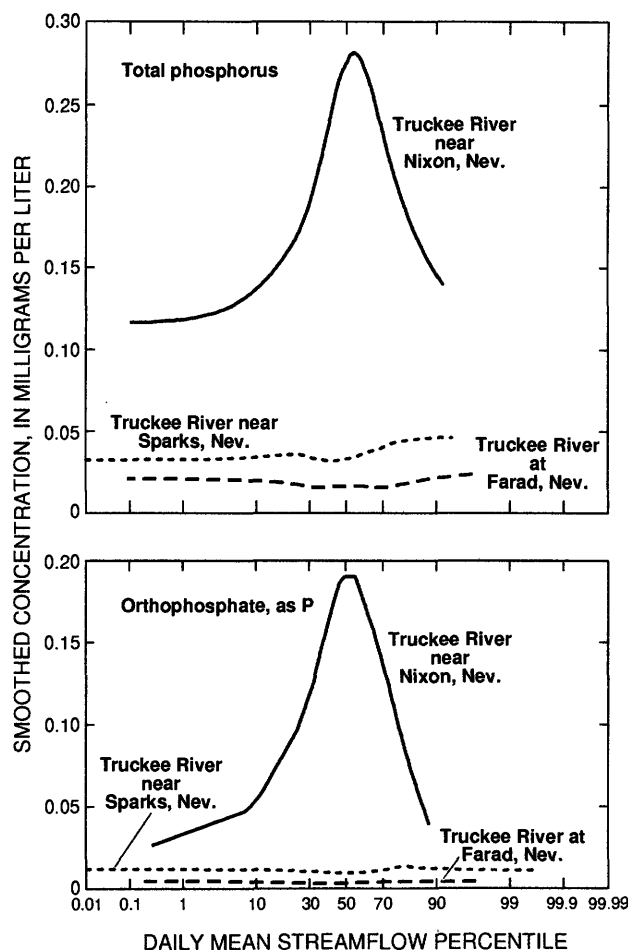


Figure 49. Relation of smoothed concentrations of total phosphorus and orthophosphate concentrations to streamflow percentiles for Truckee River at Farad, Calif., Truckee River near Sparks, Nev., and Truckee River near Nixon, Nev., water year 1970 through April 1990. Daily mean streamflow values were converted to percentiles to facilitate comparison of relations among stations with different magnitudes of flow; 100th percentile corresponds to highest recorded daily mean flow and 50th percentile corresponds to median daily mean streamflow.

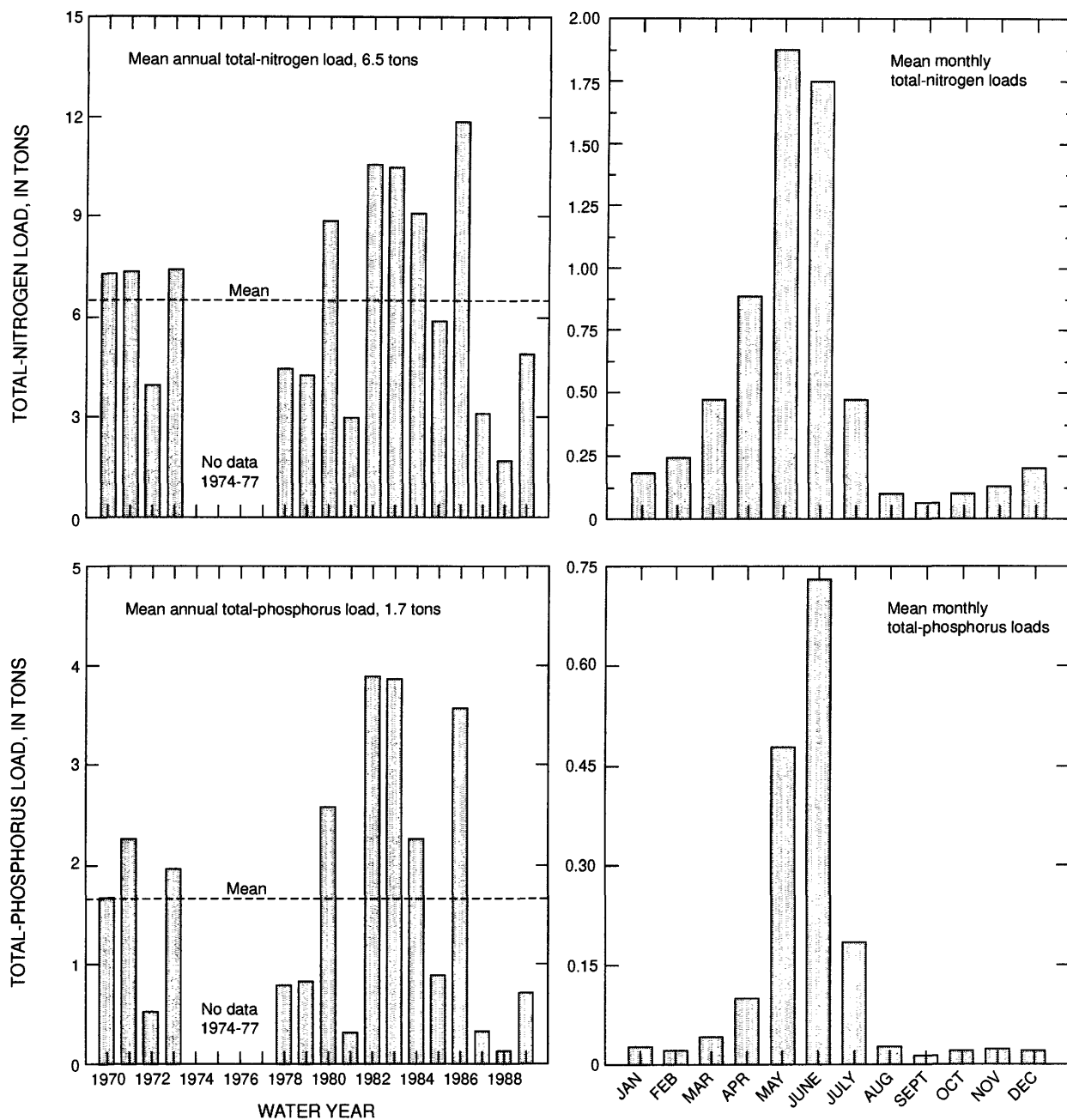


Figure 50. Yearly and mean monthly total-nitrogen and total-phosphorus loads for Third Creek near Crystal Bay, Nev., water years 1970-89.

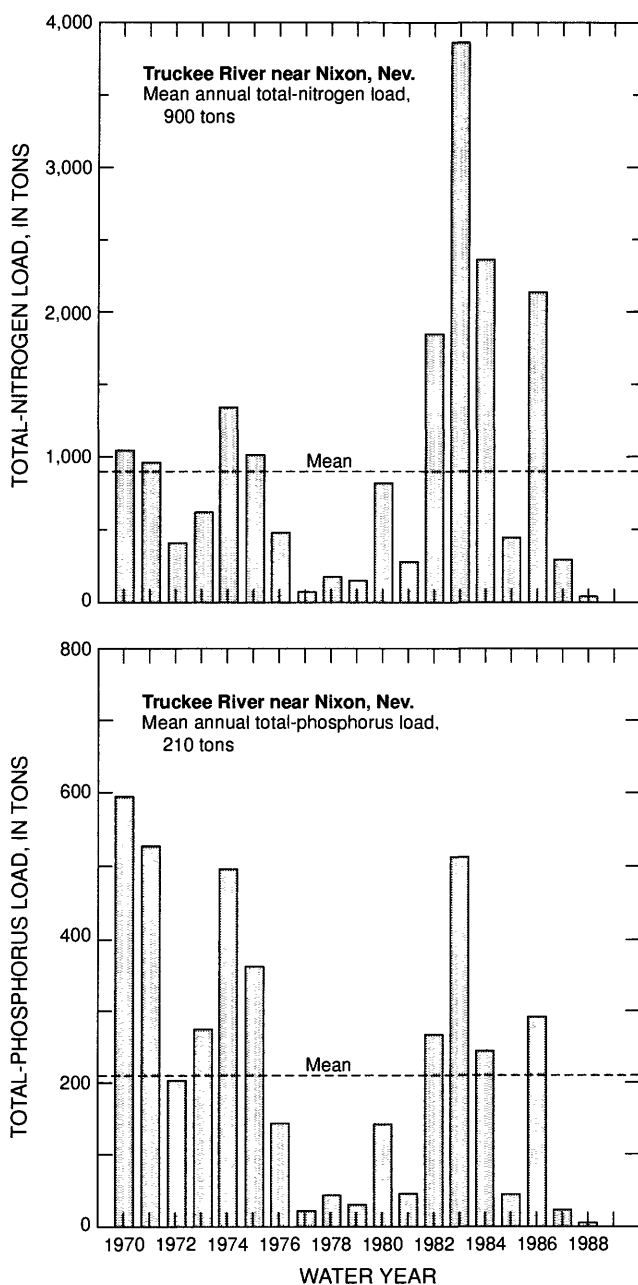


Figure 51. Yearly total-nitrogen and total-phosphorus loads for Truckee River near Nixon, Nev., water years 1970-88.

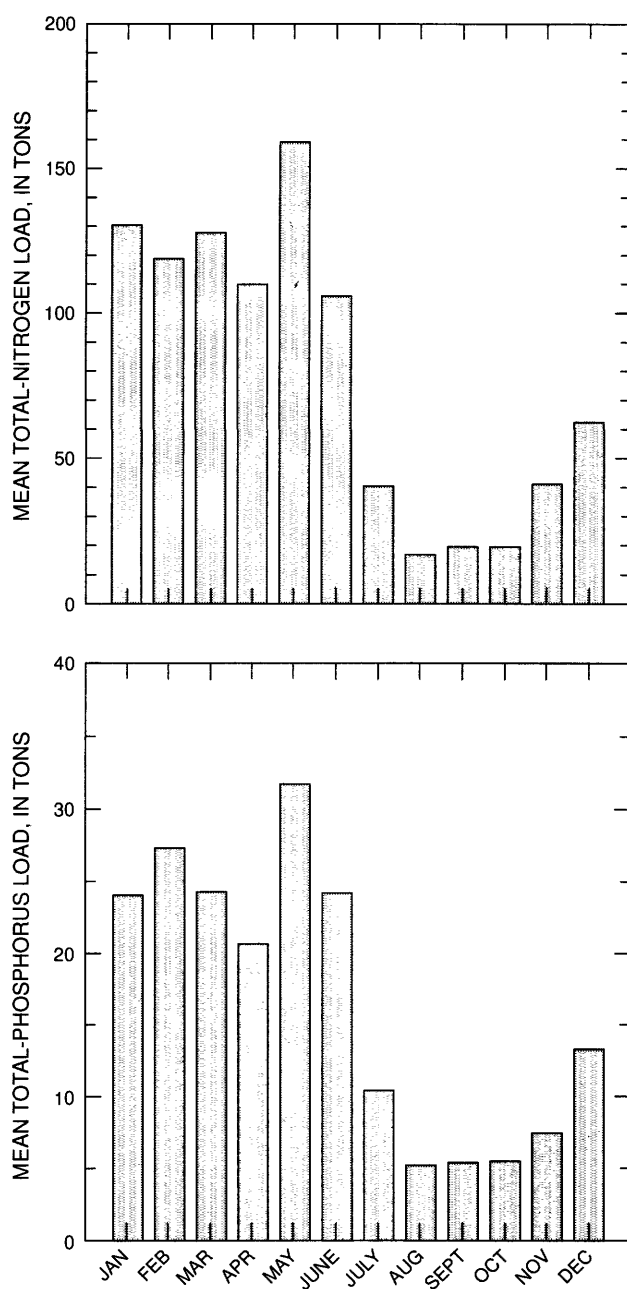


Figure 52. Mean monthly total-nitrogen and total-phosphorus loads for Truckee River near Nixon, Nev., water years 1970-88.

NUTRIENTS IN GROUND WATER

By Michael S. Lico

INTRODUCTION

Contamination of ground water is becoming an increasingly important concern in Nevada as the population of the State grows. Increased development of the limited water resources of Nevada makes it even more imperative that these resources be protected from contamination. Land-use activities can create the potential for contamination of the shallow aquifers beneath the activities. Nutrient species (orthophosphate, ammonia, and nitrate) are important potential contaminants that can be introduced by land-use activities. Some activities that could contribute nutrients to ground water are urban and agricultural fertilization of lawns and crops, leaking sewage-collection systems, animal wastes, land application of treated sewage effluent, and septic-tank discharge. Natural sources of nitrogen and phosphorus, such as organic matter and evaporites, also can cause high concentrations of nutrients in ground water. Shallow aquifers in the study area are especially vulnerable to contamination because of the potential for infiltration of contaminated water through the unsaturated zone to the water table. In parts of the study area, such as the Carson Desert, the shallow aquifers are a primary source of drinking water. In other parts of the study area, the principal aquifers underlie shallow aquifers and, potentially, can be contaminated by downward leakage.

Purpose and Scope of This Section

The purpose of this section of the report is to evaluate data on ground-water quality collected during water year 1970 through April 1990 in the Nevada Basin and Range study unit of the National Water-Quality Assessment Program (NAWQA). Water-quality data include species of phosphorus and nitrogen (more specifically, dissolved orthophosphate, ammonia, and nitrate) in ground-water samples from the Las Vegas Valley and Carson and Truckee River Basins. These data and associated hydrologic and land-use information were evaluated to ascertain whether nutrient concentrations are related to any of the associated attributes.

Approach

A thorough examination of available ground-water-quality data in the Las Vegas Valley and Carson and Truckee River Basins was made. Reports documenting nutrient concentrations in ground water, regional basin studies, and contamination studies (described in the section titled "Previous Investigations") were reviewed for information pertaining to the study area. Available data for water year 1970 through April 1990 were accessed and evaluated, including NWIS (Maddy and others, 1989), STORET, State, and county sources. The level of quality assurance of the data from some of these sources was not clearly indicated. Thus, in the statistical analysis of the available data, only the USGS data were used because collection, analysis, and reporting of data were done in accordance with documented protocols. Ground-water sites used in this section are shown on plates 1 and 2 and are listed in appendix B.

Previous Investigations

Las Vegas Valley Area

In a report recommending a monitoring network design for Las Vegas Valley, Dettinger (1987) listed nutrient data for shallow, intermediate, and deep aquifers. Samples from 40 wells were collected and analyzed for nutrients during 1981-83. Conclusions drawn by Dettinger were that areas of high nitrate concentrations in the shallow aquifer were related to sewage, lawn irrigation, and fertilizer application. Nitrate concentrations ranged from less than 0.1 to 18 mg/L as N and orthophosphate concentrations ranged from less than 0.01 to 2.3 mg/L as P.

An investigation of high-nitrate ground water northwest of Las Vegas, near Gilcrease Ranch, reported by Patt and Hess (1976) and Hess and Patt (1977), provides numerous nitrate data. Within this area, about 40 percent of the wells sampled had nitrate concentrations greater than the primary drinking-water standard (MCL) for nitrate. High concentrations were detected in samples collected from the top of the water table and to a depth of about 145 ft. The authors attributed the high nitrate concentrations to natural sources (organic or evaporite minerals) and not fertilizer, human, or animal waste. Their conclusions were based on volumetric considerations of potential sources.

A report by Plume (1985) on the water resources of Kyle and Lee Canyons in the Spring Mountains, headwaters area for the Las Vegas Valley, contains ammonia and nitrate data. Five wells in Kyle Canyon and four wells in Lee Canyon were sampled as part of this study. In Kyle Canyon, ammonia concentrations ranged from below detection (reported as 0 mg/L) to 0.07 mg/L as N and nitrate (expressed as nitrate plus nitrite) ranged from 0.01 to 0.34 mg/L as N. In Lee Canyon, ammonia concentrations ranged from 0 to 0.08 mg/L as N and nitrate ranged from 0 to 0.27 mg/L as N. Plume concluded that septic-tank effluent has affected ground-water quality in Kyle Canyon and possibly in Lee Canyon.

A study of the potential effects of different uses of reclaimed wastewater (Orcutt, 1965) evaluated samples collected from wells in North Las Vegas and in Las Vegas. Twenty-three wells sampled in North Las Vegas had nitrate concentrations ranging from less than detection (reported as 0 mg/L) to 24.6 mg/L as NO_3 . Another five wells operated by the Las Vegas Valley Water District had nitrate concentrations ranging from 2.6 to 6.2 mg/L as NO_3 .

Thomas and others (1991) reported the concentrations of nutrients for water samples from wells and springs in Las Vegas Valley associated with the carbonate-rock terrane of southern and eastern Nevada. They reported nitrate concentrations for 34 samples that ranged from less than 0.1 to 2.0 mg/L as N. Ammonia and orthophosphate concentrations (nine samples each) ranged from 0.01 to 0.07 mg/L as N and from less than 0.01 to 0.06 mg/L as P.

A report describing the effects of land and water use on water quality in Las Vegas Valley (Kauffman, 1978) contains nitrate data for shallow and deep aquifers. In general, Kauffman concluded the deep ground water had nitrate concentrations of 5 mg/L (as NO_3) or less, unless shallow ground water was leaking along the well casing. Nitrate concentrations in shallow ground water were influenced by the distribution of septic systems and areas of sewage disposal. High nitrate concentrations were common in the shallow ground water, especially in the eastern part of the valley.

A report describing the quality of water in aquifers near the Whitney area of Las Vegas Valley (Emme and Prudic, 1991) contains nitrate and ammonia data. In the Whitney area, nitrate concentrations in samples from 13 shallow wells ranged from 0.1 to 26 mg/L as N, with a median concentration of 4.5 mg/L as N. Ammonia concentrations in samples from 13 wells

ranged from 0.18 to 6.5 mg/L as N and had a median concentration of 0.28 mg/L as N. The authors noted that the highest nitrate values were near sewage ditches and areas where sewage sludge was applied.

Elsewhere in the Las Vegas Valley, ground-water samples were collected and analyzed from the shallow (less than or equal to 100 ft), intermediate (between 100 and 300 ft), and deep (greater than 300 ft) aquifers (Dinger, 1977). Samples from the shallow aquifer (35 samples) had an average nitrate concentration of 13 mg/L as N. Samples from the intermediate aquifer (250 samples) had an average nitrate concentration of 3.2 mg/L as N and those from the deep aquifer (3 samples) had an average nitrate concentration of 2.3 mg/L as N.

Carson River Basin

Previous investigations of ground-water quality in the Carson River Basin are numerous. However, not all the reports describing these investigations contain analytical results for nutrient species. Generally, two types of investigations have been made in the Carson River Basin: (1) general reconnaissance-type studies where either the entire basin or a large part of it was studied, and (2) studies to provide information on specific problems in specific geographic parts of the basin.

An early reconnaissance study of ground water in the Carson River Basin is described in a report by Glancy and Katzer (1976). They noted that in Dayton Valley, downstream from Dayton, more than one-third of the wells had nitrate concentrations in excess of 10 mg/L as NO_3 . They speculated that waters containing high concentrations of nitrate may extend as far east as Silver Springs. The source of nitrate was attributed to septic tanks in the area.

A report describing the chemical composition of water flowing from springs in the Sierra Nevada (Feth and others, 1964) contains the analyses for 12 springs in the Carson and Truckee River Basins. Nitrate concentrations for these samples ranged from below detection (reported as 0 mg/L) to 2.2 mg/L as NO_3 .

Sertic and others (1988) provide a detailed description of water quality in the Carson River Basin. Their report includes both surface- and ground-water data associated with many types of land use. Nitrate, ammonia, and orthophosphate concentrations measured in water samples from monitoring wells in Carson Valley near sewage-effluent disposal sites, a landfill, several domestic wells, and an industrial site were summarized. Nitrate concentrations ranged from less than 0.01 to 20 mg/L as N, ammonia from less than

0.01 to 0.35 mg/L as N, and orthophosphate from less than 0.02 to 0.37 mg/L as PO_4 . In Eagle Valley, data from an industrial site, sewage-influenced areas, domestic wells, and a contaminated site (leaking gasoline tank) were given. Nitrate concentrations for samples from domestic wells ranged from less than detection (reported as 0 mg/L) to 17.5 mg/L as N. Nitrate analyses of well- and spring-water samples were given for Dayton and Churchill Valleys and ranged from less than detection (reported as 0 mg/L) to 0.14 mg/L as N. In Carson Desert, analyses for nitrate, ammonia, and orthophosphate were given for water samples from domestic wells, wells in agricultural areas, and from tile drains. Water samples from wells had nitrate concentrations ranging from less than 0.1 to about 3.4 mg/L as N, and one sample from a well in an industrial area had a concentration of 20 mg/L as N. Tile-drain water samples, collected from beneath a wheat field near Fallon, had high nitrate concentrations that ranged from 11 to 36 mg/L as N. Ammonia concentrations generally were low in all samples from wells and tile drains, and ranged from less than 0.1 to 0.23 mg/L as N. Orthophosphate concentrations were low in samples from wells (0.08 to 0.046 mg/L as PO_4) and somewhat higher in tile-drain water samples (0.029 to 1.4 mg/L as PO_4).

Garcia (1989) investigated the ground-water quality of Douglas County, which includes Carson Valley, and reports numerous nitrate analyses of water samples. Garcia summarized nitrate concentrations in ground-water samples from 323 sites in the County. The median nitrate concentration for samples from wells less than 200 feet deep was 3.1 mg/L (as NO_3) and for those greater than 200 feet deep was 2.4 mg/L (as NO_3).

Another reconnaissance report on ground water in the Carson River Basin summarized all available water-quality data (Welch and others, 1989). Data analyzed for this report included nitrate as the only nutrient species. For the entire basin, nitrate concentrations were greater than the primary drinking water standard (10 mg/L as N) in only 10 of 742 samples.

Smaller areas in the Carson River Basin have been studied by several investigators. An earlier report by Worts and Malmberg (1966) described the ground-water conditions in Eagle Valley. Four nitrate analyses of water samples from public-supply wells were reported and ranged from about 0.02 to 1.8 mg/L as N. These authors expressed concern about the influence of septic systems on ground-water quality.

A report on the water quality of Carson Valley by Thodal (1992a) includes the results of chemical analyses from 35 sites. Samples were collected and analyzed from one to four times at each site. Nitrate and ammonia concentrations ranged from less than 0.1 to 12 mg/L as N and from less than 0.01 to 0.84 mg/L as N, respectively. The median concentrations of nitrate and ammonia were 0.39 mg/L and 0.01 mg/L as N, respectively.

Data collected by the Carson River Basin NAWQA pilot project were reported by Whitney (1994) and details of water quality in Carson and Eagle Valleys, Dayton and Churchill Valleys, and Carson Desert are contained in reports by Welch (1994), Thomas and Lawrence (1994), and Lico and Seiler (1994), respectively. Welch and others (1997) summarized the findings of the Carson River Basin NAWQA project in their report.

The Bureau of Reclamation (1987) documented the ground-water quality of part of the Fallon Indian Reservation. The Bureau sampled six wells as part of the project and found nitrate concentrations ranging from less than 0.1 to 111 mg/L as N.

Studies done at and near Stillwater Wildlife Management Area (WMA) include nutrient data. Hoffman and others (1990), as part of a reconnaissance study of wetlands in Stillwater WMA and Carson Lake, reported the results of the analyses of six ground-water samples. Ranges of concentrations for these samples were as follows: nitrate, from less than 0.1 to 0.33 mg/L as N; ammonia, 0.37 to 34 mg/L as N; and orthophosphate, from 0.09 to 0.77 mg/L as P. Rowe and others (1991) reported the results of ammonia analyses from eight wells in Stillwater WMA. Concentrations ranged from 0.11 to 4.7 mg/L as N. One sample from a geothermal well was analyzed for nitrate, ammonia, and orthophosphate, as N and P (0.08, 2.6, and 0.3 mg/L, respectively). Lico (1992) used these data to calculate un-ionized ammonia concentrations and determined that concentrations were high enough to exceed the criterion (0.0164 mg/L as N) for protection of aquatic life.

The occurrence and distribution of nitrate and ammonia concentrations in shallow ground water beneath the urban area of Carson City has been documented (Lawrence, 1996). Conversion of nitrogenous organic matter, percolating sewage, or nitrogen-based fertilizer were given as possible sources of nitrate and ammonia.

A study of nitrates in playas in Nevada is summarized in a report by Leatham and others (1983). Although no ground-water data were collected, high nitrate concentrations, as indicated by analyses of playa material, suggest that playas may be sinks for nitrogen. Carson Sink, one of the sites studied, had the lowest nitrate concentration (2.7 mg/kg as N) of any playa in the general area.

Truckee River Basin

Previous studies of ground-water quality in the Truckee River Basin have been described in different reports. The water quality of the Truckee River Basin was outlined in a report by Van Denburgh and others (1973). In that report, nitrate concentrations ranged from less than detection (reported as 0 mg/L) to about 31 mg/L as N. High nitrate concentrations were especially prevalent in the Tracy Segment area downstream from Reno.

A study of nutrient loads to Lake Tahoe by ground-water seepage is described in a report by Loeb and Goldman (1979). Their study of a small watershed (Ward Creek) on the west shore of the lake indicated that ground water contributed about 49 percent of the nitrate load from this watershed to the lake. They concluded that about 44 percent of the orthophosphate load from this subbasin to the lake was from ground-water seepage. In another report, Loeb (1987) describes the ground-water quality of three major aquifers in the Lake Tahoe Basin and the contribution of nutrients to the lake. He found that shallow aquifers near Trout Creek in South Lake Tahoe had the highest nitrate concentrations and that concentrations increased closer to the lake. Possible sources for the nitrate were fertilizers, exfiltration through sewer lines, and increases in nitrification following land disturbance. For the watersheds studied, from 5 to 60 percent of the nitrate load and 2 to 45 percent of the orthophosphate load to the lake were estimated to be from ground-water seepage.

Ground-water data for the Lake Tahoe Basin collected during 1986 and 1987 are presented by Thodal (1992b). Forty-eight samples were collected from wells and springs, mostly in the eastern and southern parts of the basin. Nitrate concentrations ranged from less than 0.01 to 8.2 mg/L as N and had a median value of 0.028 mg/L as N. Ammonia concentrations ranged from less than 0.002 to 0.89 mg/L as N and had a median concentration of 0.03 mg/L as N.

Orthophosphate concentrations ranged from less than 0.001 to 0.049 mg/L as P and had a median concentration of 0.007 mg/L as P.

The hydrologic conditions at Verdi, in the Truckee River Basin, are described in a report by Schmidt (1980). Results of nitrate analysis from six ground-water samples in the Hill Lane subarea ranged from less than about 0.2 to 2.7 mg/L as N and five samples from the Sierra Pines subarea ranged from less than detection (reported as 0 mg/L) to about 0.2 mg/L as N.

Cohen and Loeltz (1964) reported on the hydrogeology and hydrogeochemistry of the Truckee Meadows area. Included in their report were the results of chemical analysis of ground-water samples that had nitrate concentrations ranging from less than detection (reported as 0 mg/L) to about 3.3 mg/L as N. One high nitrate value of about 24 mg/L as N was reported from a shallow well in the Truckee Meadows.

A study of irrigation drainage in the Fernley area (Rowe and others, 1991; Lico, 1992) included 11 ground-water sites throughout the basin. Nitrate concentrations in samples from these wells ranged from 0.01 to 2.6 mg/L as N, ammonia was less than 0.01 to 0.42 mg/L as N, and orthophosphate ranged from 0.02 to 0.75 mg/L as P.

Methods and Limitations of Data

Data from the USGS NWIS data base (Maddy and others, 1989) were assembled into a file containing the following information: physical details such as location, depth, well-construction information; concentrations of nutrients, such as dissolved orthophosphate, ammonium, and nitrate; concentrations of other chemical constituents; and land-use information. For this report, the most recent analysis was used for sites with more than one sample analysis during the study period (water year 1970 through April 1990). In some areas, several sites are concentrated in a small geographic area. In these areas, one site was chosen to represent the area, to prevent bias of the statistical analysis. Well waters that had temperatures greater than 35°C were not used in the statistical analysis because water from these wells is considered not representative of the sources used for human activities. Ground-water sites are listed in appendix B and shown on plates 1 and 2.

The data, as described above, were subjected to two statistical procedures designed to describe the distribution of nutrient concentrations in relation

to land-use type, depth of well, or physiographic location. Boxplots were constructed using percentile values for each nutrient species included in this report.

The Mann-Whitney test was applied to all different populations defined for this study. This two-sided nonparametric t-test is designed to evaluate whether two groups of data are from different populations. This t-test calculates a value called the "*p*-value," which is the smallest level of significance that would allow the null hypothesis to be rejected. In other words, a *p*-value of 0.05 represents a 95-percent confidence that the populations are different (Iman and Conover, 1983). Criteria used to determine significance are as follows: (1) *p*-value less than or equal to 0.01 is highly significant, (2) *p*-value greater than 0.01 but less than or equal to 0.05 is significant, and (3) *p*-value greater than 0.05 is not significant.

For comparison, ground-water nutrient data were divided into categories chosen to represent physical, chemical, or cultural factors that could influence the distribution and concentration of nutrients in ground water from the study area. Land use in the general area of well sites can be a very important factor influencing nutrient concentrations in the ground water, especially in the shallow water-table aquifer. Land use for each well site was determined from digital data derived from 1973-83 coverage (pls. 1 and 2). For the purposes of this study, land use was divided into seven categories—urban, agriculture, range, forest, water, wetland, and barren. Further grouping of land uses for statistical analysis in this section of the report was done to include range, forest, and barren into a single category "range," and open water and wetlands into a "wetlands" category. For final data analysis, four categories were used: urban, agriculture, range (range plus forest and barren), and wetlands (wetlands plus open water).

Ground-water quality data also were categorized by the depth of the well. Wells with depths less than or equal to 50 ft were placed into a shallow-aquifer category and those with depths greater than 50 ft were placed into a deep-aquifer category. This is an artificial boundary, but it is consistent with previous reports (Glancy, 1986; Lico and Seiler, 1994; Maurer and others, 1996). The basis for this categorization is that the shallow aquifers should be more susceptible to contamination from land-surface activities, and the deep aquifers should be somewhat protected from these activities and more representative of water compositions caused by natural processes.

The final categorization of ground-water-quality data was the relation of the well site to either headwater or basin areas of the study area. Headwater areas are high mountains and parts of adjacent valleys where precipitation is adequate to cause runoff that sustains streamflow and recharges ground water. Basin areas are low mountains and valleys with little or no locally generated runoff or recharge. However, basin valleys can receive recharge from streams or ground-water flow from headwater areas. Some general assumptions are inherent in the classification of wells by these criteria. Recharge is by irrigation in the agricultural areas in Carson Desert. An alternative way to view headwater and basin categories is to think of "distance down the flow system," with water in the headwater areas having less time to react with the minerals and water in the basin areas having more time to react.

The different types of data used in the statistical analysis for this report can have some limitations. The data were collected for several projects or monitoring networks that were not designed to answer the questions posed here. Some limitations of the data are:

(1) The areal distribution of data-collection sites was not chosen at random, except for the Carson River Basin data collected by the NAWQA pilot study. Data collected for specific project objectives can be biased depending on what the project objectives were. Data that were clustered in a small geographic area were "filtered" by using only one representative sample from those groups.

(2) When data are divided into categories, some of the categories do not have enough samples to be a statistically valid representation of the population. For such categories, *p*-values were not calculated and no interpretations were attempted.

(3) Samples are not distributed uniformly throughout the entire study area. Some of the valleys within the study area have only a few samples while others have many.

(4) The land-use coverage was done during 1973-83. Water-quality samples collected since then may represent some other land-use category than indicated by the land-use map (pls. 1 and 2). This may be especially true in rapidly growing urban areas such as Reno and Las Vegas.

(5) Multiple land uses or nearby land uses are not considered in this analysis. Sampling sites near the edges of a particular land-use area can be affected by the adjacent land use.

(6) During the period of study, analytical procedures for the determination of nutrient species have changed. Also, a positive bias in ammonia has been documented for analyses by the U.S. Geological Survey laboratory in Arvada, Colo., during the early 1980's (Alexander and others, 1993).

Distribution of Nutrient Concentrations in Ground Water

In this section of the report, concentration ranges of nutrient species (orthophosphate as P, ammonia as N, and nitrate as N) and their significance is given below. Boxplots for concentration ranges of each nutrient are shown by categories representing physical, chemical, and cultural factors, and these groups were tested to determine if they were from the same or different populations. Associated *p*-values, calculated using the Mann-Whitney *t*-test, are shown and discussed.

Comparison of Headwater and Basin Areas

Headwater areas represent the upstream (recharge) parts of the basins within the study unit. Basin areas are where evapotranspiration exceeds the rate of recharge. Headwater areas are delineated on plates 1 and 2. Because of the different dominant processes in these two areas, each area would be expected to have a unique assemblage of nutrient concentrations. The numbers of ground-water samples available for statistical analysis from headwater and basin areas are listed in table 8 for orthophosphate, ammonia, and nitrate.

Nutrient concentrations in the shallow aquifers were, at a highly significant level (*p* less than 0.01), greater in basin areas than in headwater areas (table 9). In deep aquifers, ammonia was the only nutrient that had higher concentrations, at a highly significant level, in basin areas than in headwater areas.

Concentrations of orthophosphate in samples of ground water from the shallow aquifers ranged from less than 0.01 to 0.58 mg/L as P in the headwater areas. In basin areas, shallow ground water had orthophosphate concentrations ranging from less than 0.01 to 2.3 mg/L as P. Median orthophosphate concentrations for headwater and basin areas were 0.034 and 0.29 mg/L, respectively in the shallow aquifers (fig. 53). The two populations, headwater and basin, were different at the highly significant level (*p* less than 0.01, table 9) with concentrations being higher in the basin areas. Samples

Table 8. Numbers of ground-water samples used to evaluate orthophosphate, ammonia, and nitrate in Nevada Basin and Range NAWQA study unit, water year 1970 through April 1990

Category	Number of samples			
	Study unit	Las Vegas Valley	Carson River Basin	Truckee River Basin
Dissolved orthophosphate				
All land uses	332	43	226	63
Urban land use	69	17	38	14
Agricultural land use	101	0	99	2
Range land use	150	24	83	43
Wetland land use	12	2	6	4
Shallow aquifers	105	5	74	26
Deep aquifers	227	38	152	37
Headwater areas	184	0	125	59
Basin areas	148	43	101	4
Dissolved ammonia				
All land uses	362	61	244	57
Urban land use	71	18	39	14
Agricultural land use	109	1	106	2
Range land use	165	34	93	38
Wetland land use	17	8	6	3
Shallow aquifers	143	37	80	26
Deep aquifers	219	24	164	31
Headwater areas	194	9	133	52
Basin areas	168	52	111	5
Dissolved nitrate				
All land uses	363	57	250	56
Urban land use	72	17	41	14
Agricultural land use	111	0	109	2
Range land use	162	31	94	37
Wetland land use	18	9	6	3
Shallow aquifers	131	26	79	26
Deep aquifers	232	31	171	30
Headwater areas	186	0	134	52
Basin areas	177	57	116	4

from deep aquifers were not significantly different in orthophosphate concentrations between headwater and basin areas (*p* equals 0.15). Concentrations ranged from less than 0.001 to 0.26 mg/L in headwater areas and from less than 0.01 to 7.5 mg/L in basin areas. Median orthophosphate concentrations in the deep aquifers were 0.03 and 0.02 mg/L for headwater and basin areas, respectively (fig. 53).

Dissolved ammonia concentrations in the shallow aquifers ranged from less than 0.002 to 0.89 mg/L as N in the headwater areas and from less than 0.01 to

Table 9. Associated *p*-values for Mann-Whitney two-tailed test comparing concentrations of orthophosphate, ammonia, and nitrate in ground-water samples from headwater and basin areas for shallow and deep aquifers of Nevada Basin and Range NAWQA study unit

[A *p*-value less than or equal to 0.01 is considered highly significant and a *p*-value greater than 0.05 is not significant; shallow aquifers extend from near land surface to depths of about 50 feet; deep aquifers are greater than 50 feet below land surface. Bold value indicates that concentrations are greater in basin areas than in headwater areas.]

Aquifer	Ortho-phosphate	Ammonia	Nitrate
Shallow	less than 0.01	less than 0.01	less than 0.01
Deep	equals .15	less than .01	equals .73
All aquifers combined	less than .01	less than .01	equals .01

34 mg/L in basin areas. Median ammonia concentrations for shallow aquifers in headwater and basin areas were 0.035 and 0.20 mg/L, respectively (fig. 53). Ammonia concentrations in shallow aquifers for headwater and basin areas were different at a highly significant level (*p* less than 0.01, table 9). In deep aquifers, ammonia concentrations were higher in basin areas than in headwater areas at a highly significant level (*p* less than 0.01). Ammonia concentrations in deep aquifers ranged from less than 0.001 to 0.50 mg/L in headwater areas and from less than 0.001 to 3.3 mg/L in basin areas. Median ammonia concentrations in deep aquifers were 0.01 mg/L for headwater areas and 0.06 mg/L for basin areas.

Dissolved nitrate concentrations in the shallow aquifers ranged from less than 0.005 to 17 mg/L as N in the headwater areas and from 0.09 to 27 mg/L in the basin areas. Median nitrate concentrations in shallow aquifers for headwater and basin areas were 0.1 and 1.0 mg/L (fig. 53), respectively. Results of the nonparametric t-test (table 9) indicated that nitrate concentrations for shallow aquifers in basin areas were higher than those in headwater areas at a highly significant level (*p* less than 0.01). Deep aquifers within the study area were not significantly different in nitrate concentrations between headwater and basin areas. Ranges for nitrate concentrations in deep aquifers were 0.009 to 20 mg/L for headwater areas and 0.10 to 7.8 mg/L for basin areas. Median values of nitrate concentrations for deep aquifers in headwater and basin areas were similar, at 0.33 and 0.36 mg/L, respectively.

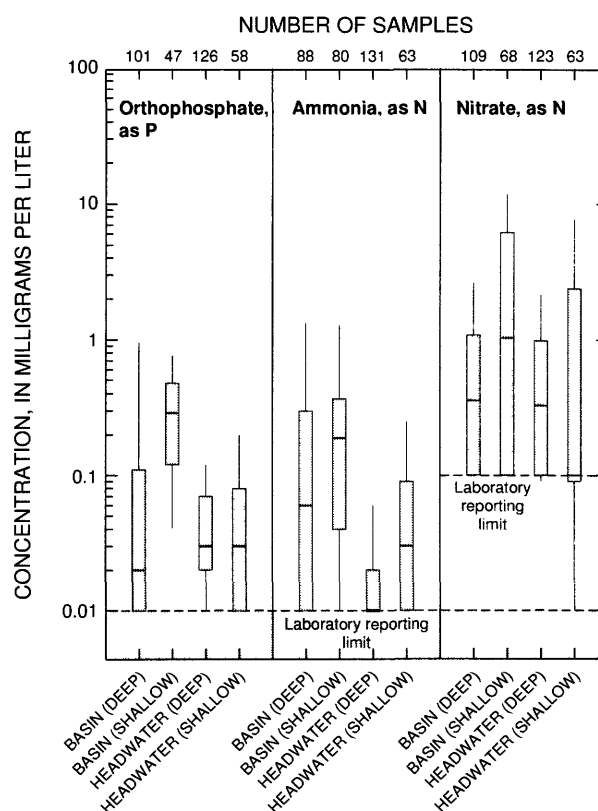


Figure 53. Distribution of orthophosphate, ammonia, and nitrate concentrations in ground-water samples from shallow (50 feet or less) and deep aquifers in basin and headwater areas of Nevada Basin and Range NAWQA study unit. Laboratory reporting limits shown as dashed lines; nitrate had two different laboratory reporting limits because two separate methods were used for analysis.

Effects of Land Use on Nutrients

Land use potentially can have major effects on the quality of ground water, especially in shallow aquifers. Land uses can include natural states, such as forest, range, and wetlands, as well as urban and irrigated agricultural areas. In areas of mixed land uses, exact factors that influence ground-water quality can be especially difficult to determine. The four land uses considered for this analysis were urban, agricultural, range (range and forest), and wetland (wetlands and open water), as shown on plates 1 and 2. The number of samples available for each land-use category is listed in table 8.

For all samples in the study area, dissolved orthophosphate concentrations in ground water were significantly higher in agricultural areas than in other land-use areas. Concentrations were different at the highly

significant level (p less than 0.01) between agricultural areas and both urban and range areas. The difference between agricultural areas and wetland land areas was significant (p equals 0.02). Differences in orthophosphate concentrations between urban areas and range areas were not significant. Dissolved ammonia concentrations were higher, at the highly significant level (p less than 0.01), in wetland areas than in all other areas.

No significant differences in ammonia concentrations were found among other land-use areas. Concentrations of dissolved nitrate were not significantly different among land-use areas.

If samples are further divided into shallow and deep aquifers (fig. 54), orthophosphate concentrations as P in shallow aquifers were not significantly different in range areas (median, 0.04 mg/L) and urban areas

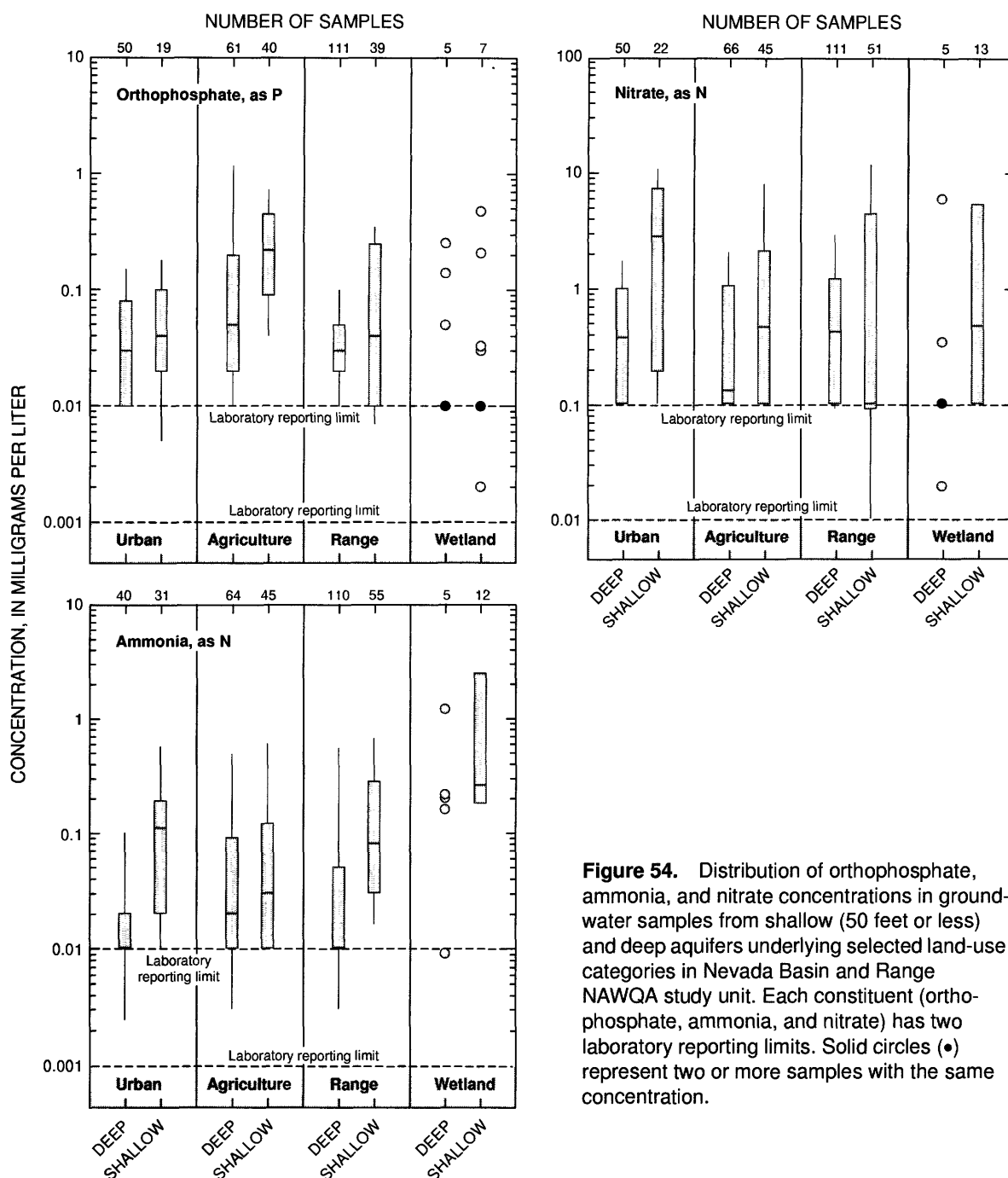


Figure 54. Distribution of orthophosphate, ammonia, and nitrate concentrations in ground-water samples from shallow (50 feet or less) and deep aquifers underlying selected land-use categories in Nevada Basin and Range NAWQA study unit. Each constituent (orthophosphate, ammonia, and nitrate) has two laboratory reporting limits. Solid circles (•) represent two or more samples with the same concentration.

(median, 0.04 mg/L; p greater than 0.05). Agricultural areas had shallow ground-water samples with orthophosphate concentrations that were higher (median, 0.22 mg/L) than urban and range areas at the highly significant level (p less than 0.01). Wetlands had a median orthophosphate concentration of 0.03 mg/L in the shallow aquifers, but too few samples (seven) were available for statistical comparison with other areas. Urban and range areas had shallow ground water with ammonia concentrations that were not significantly different (medians, 0.10 and 0.08 mg/L as N, respectively; p greater than 0.05). Conversely, ammonia concentrations (median, 0.26 mg/L) were higher in wetland areas (at the highly significant level; p less than 0.01) than for all other land uses (fig. 54). Ammonia concentrations in shallow aquifers in agricultural areas (median, 0.03 mg/L as N) were significantly lower than for all other land uses except urban (which was close to being significantly different; p equals 0.06). Dissolved nitrate concentrations in the shallow aquifers were significantly higher in urban areas (median, 2.8 mg/L as N; fig. 54) than in agricultural (median, 0.46 mg/L as N; p equals 0.04) and range areas (median, 0.01 mg/L as N; and p equals 0.01). Water samples from agricultural and range areas were not significantly different in nitrate concentrations (p greater than 0.05).

In deep aquifers, orthophosphate concentrations in ground-water samples from agricultural areas (median, 0.05 mg/L as P) were significantly higher (fig. 54) than for urban and range areas (medians, 0.03 mg/L; p less than 0.01). Ground water from urban and range areas did not have significantly different orthophosphate concentrations (p greater than 0.05). Ammonia concentrations in deep aquifers were significantly higher in agricultural areas (median, 0.02 mg/L as N; fig. 54) than in urban areas (median, 0.01 mg/L; p equals 0.04). Urban and range areas did not have significantly different concentrations of ammonia in ground-water samples. Nitrate concentrations (fig. 54) in deep ground water beneath all land uses were not significantly different (p greater than 0.05). Wetland areas were represented by only five samples and were not included in the t-test.

Because each river basin in the study area has its own physical, agriculture, and hydrologic characteristics (see Covay and others, 1996), data from each basin were analyzed independently. Some of the major features that affect each basin follow (see pls. 1 and 2). (1) Las Vegas Valley area (pl. 1) has headwaters in carbonate-rock mountains, no perennial streams issuing from mountains, a major urban center in the basin, and some land application of treated sewage effluent. Las Vegas Wash is the only

perennial stream (in and downstream from Las Vegas), and flow is composed mostly of treated sewage effluent. Las Vegas Wash empties into Lake Mead, a reservoir on the Colorado River. (2) Carson River Basin (pl. 2) has unregulated headwaters, irrigation uses, and land-surface application of treated sewage effluent in headwater valleys, no large urban areas, an impoundment on the lower part of the Carson River (that also receives flow from the Truckee River) to hold water for irrigation of 68,000 acres in the Carson Desert, a playa (Carson Sink), and an important wetland habitat near Carson Sink. (3) Truckee River Basin (pl. 2) has headwaters that include Lake Tahoe and several reservoirs, a large urban area (Reno and Sparks) with high water consumption, discharge of treated sewage effluent into the Truckee River, diversion of a large part of the Truckee River flow to the Carson River Basin for irrigation purposes, and a terminal lake (Pyramid Lake). A small subbasin, the Fernley Hydrographic Area, is included as part of the Truckee River Basin because the Truckee Canal passes through it.

Las Vegas Valley Area

Ground-water samples from all aquifers beneath the Las Vegas Valley area are not available in sufficient numbers to adequately represent all land-use areas (table 8). Agricultural and wetland areas are especially underrepresented, with zero or one sample for agricultural areas and from two to nine samples for wetland areas (table 8). Also, these land uses cover little area. Thus, results of statistical tests are not presented for agricultural and wetland areas.

Orthophosphate concentrations in ground-water samples from all aquifers were not significantly different (p greater than 0.05) for urban and range areas in Las Vegas Valley (fig. 55). These areas also had similar ranges in ammonia concentrations in the underlying ground water (fig. 55). Nitrate concentrations (fig. 55) in ground water from urban and range areas in Las Vegas Valley were not significantly different (p greater than 0.05). No samples from agricultural areas were available.

If samples are further separated into shallow and deep aquifers by land use, too few samples are available to provide a statistically valid representation of the true population for shallow aquifers. Thus, no interpretations of these data were made.

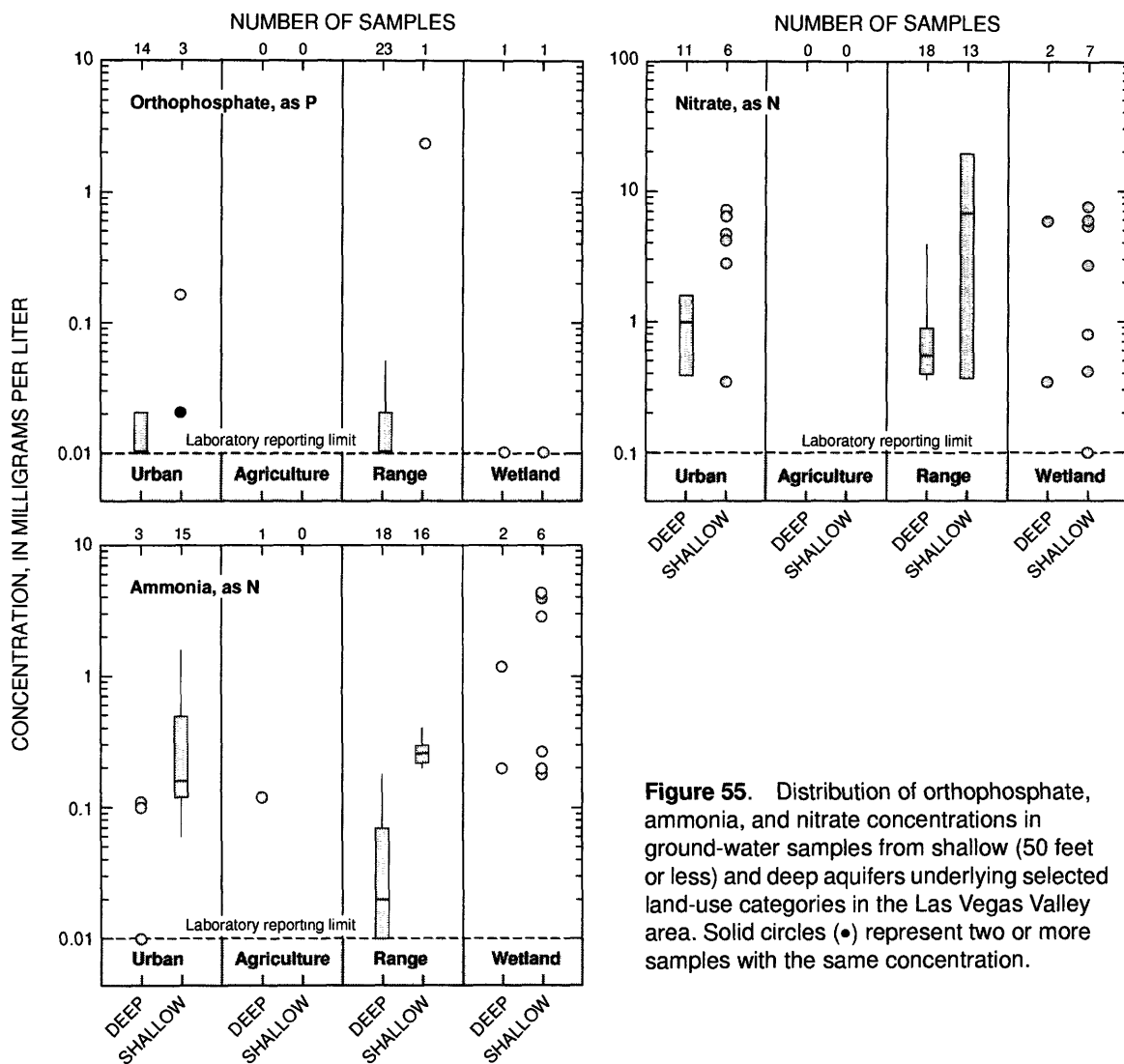


Figure 55. Distribution of orthophosphate, ammonia, and nitrate concentrations in ground-water samples from shallow (50 feet or less) and deep aquifers underlying selected land-use categories in the Las Vegas Valley area. Solid circles (•) represent two or more samples with the same concentration.

In the deep aquifers beneath Las Vegas Valley, orthophosphate concentrations were not significantly different for urban and range areas (p greater than 0.05; fig. 55). Too few data were available to determine if ammonia concentrations in the deep aquifers differed among the land-use types (fig. 55). Nitrate concentrations in the deep aquifers did not have significantly different ranges of concentration beneath urban and range areas (fig. 55).

Carson River Basin

Land use within the Carson River Basin (pl. 2) is reflected in the concentrations of nutrient species in the ground water beneath the land-use areas. Orthophosphate concentrations in ground water from shallow and deep wells combined were higher (at the

highly significant level, p less than 0.01) in agricultural areas than urban and range areas (fig. 56). Urban and range areas did not have significantly different (p greater than 0.05) concentrations of orthophosphate. Ground water in urban areas had ammonia concentrations that were significantly lower than in agricultural and range areas (fig. 56; p values were about 0.01). Concentrations of ammonia were not significantly different beneath agricultural and range areas. Dissolved nitrate concentrations in ground water from the Carson River Basin (fig. 56) were not significantly different (p greater than 0.05) for urban, agricultural, and range areas.

In shallow aquifers within the Carson River Basin, urban areas had orthophosphate concentrations that were lower than agricultural and range areas (fig. 56) at the highly significant level (p less than 0.01).

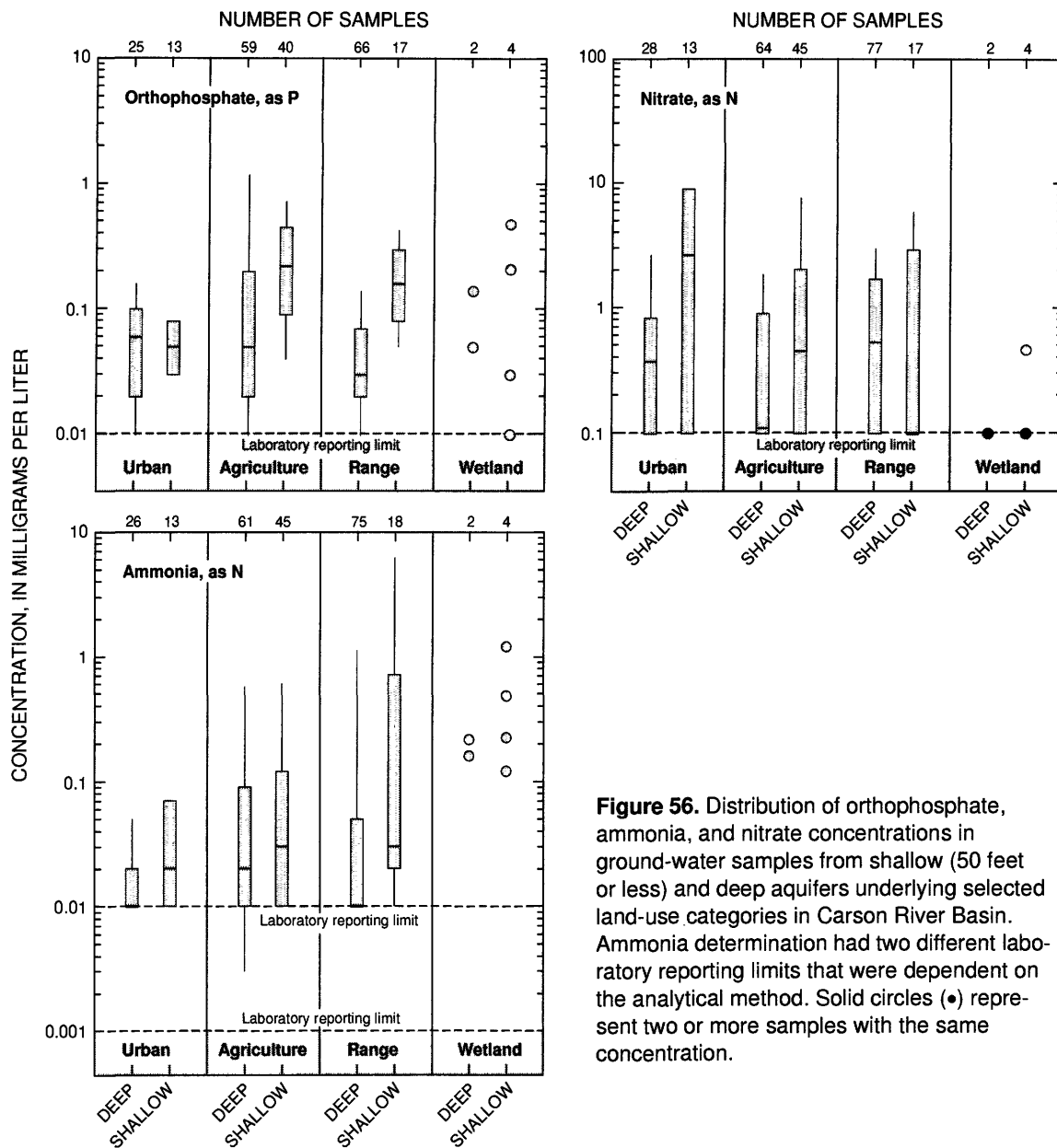


Figure 56. Distribution of orthophosphate, ammonia, and nitrate concentrations in ground-water samples from shallow (50 feet or less) and deep aquifers underlying selected land-use categories in Carson River Basin. Ammonia determination had two different laboratory reporting limits that were dependent on the analytical method. Solid circles (•) represent two or more samples with the same concentration.

Concentrations in agricultural and range areas were not significantly different (p greater than 0.05). Dissolved ammonia concentrations in shallow aquifers were not significantly different for all land uses, except perhaps wetlands (fig. 56). The four samples from the shallow aquifers beneath wetlands had higher ammonia concentrations than samples from urban and agricultural land-use areas (p less than 0.01), but this sample size may not have accurately represented the true population. All ground-water samples collected from the shallow aquifers did not have significantly different (p greater than 0.05) nitrate concentrations (fig. 56).

Truckee River Basin

Most of the land uses in Truckee River Basin (pl. 2) had only a few nutrient analyses associated with them. For aquifers with data available, orthophosphate concentrations (fig. 57) in ground-water samples from shallow and deep wells combined were lower in range areas within the Truckee River Basin than for urban areas (at the highly significant level, p less than 0.01). Ammonia concentrations (fig. 57) were not significantly different in ground-water samples from urban and range areas in the Truckee River Basin

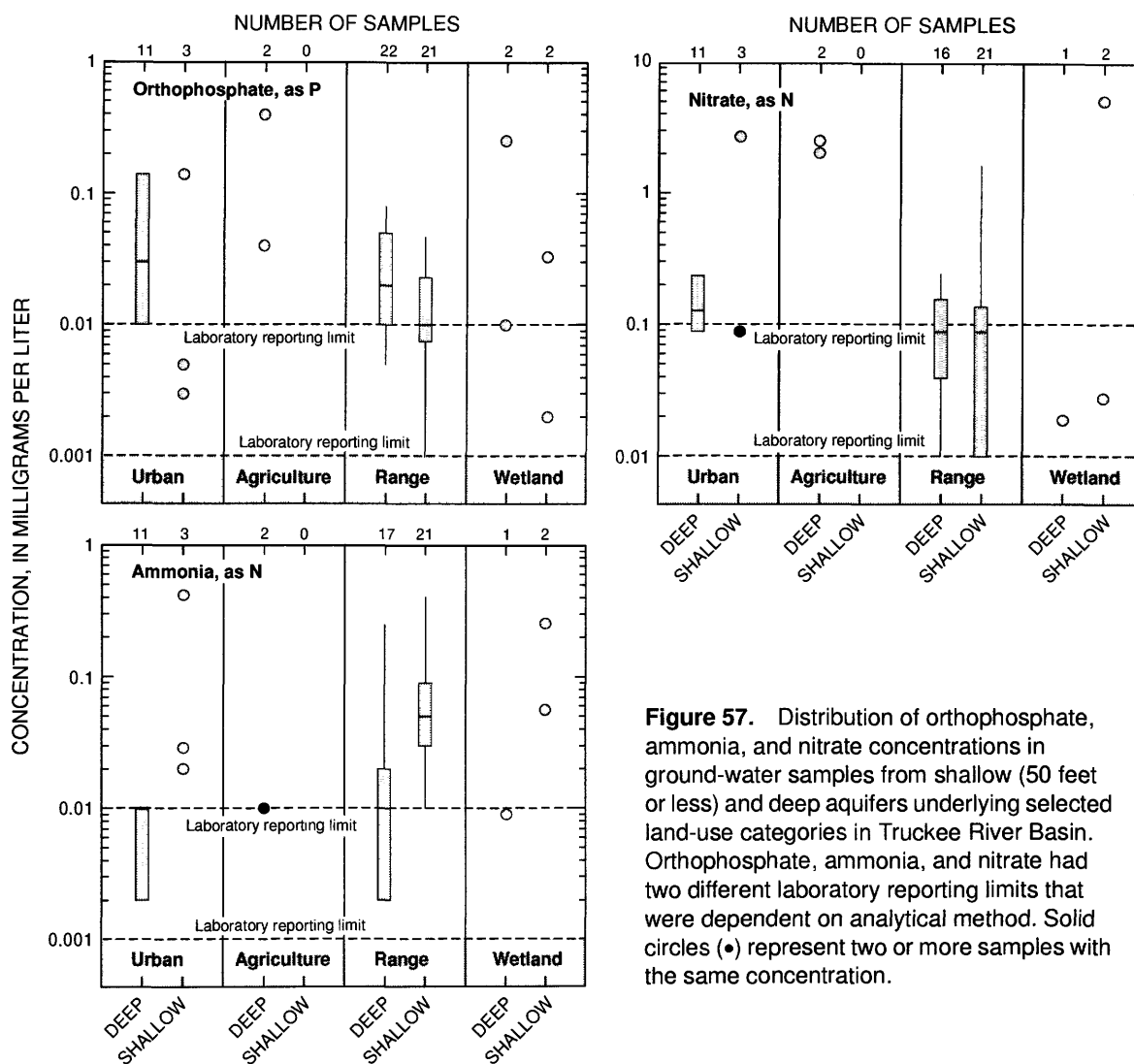


Figure 57. Distribution of orthophosphate, ammonia, and nitrate concentrations in ground-water samples from shallow (50 feet or less) and deep aquifers underlying selected land-use categories in Truckee River Basin. Orthophosphate, ammonia, and nitrate had two different laboratory reporting limits that were dependent on analytical method. Solid circles (•) represent two or more samples with the same concentration.

(p greater than 0.05). Range and urban areas had nitrate concentrations (fig. 57) in ground water that were not significantly different (p greater than 0.05).

In shallow aquifers within the Truckee River Basin, differences in nutrient concentrations in ground water caused by land use could not be discerned because of small sample sizes (zero to three samples) for urban, agricultural, and wetland areas (fig. 57).

Analyses for orthophosphate in ground-water samples from deep aquifers in the Truckee River Basin were sparse for all land uses. Orthophosphate concentrations (fig. 57) in the deep aquifers were lower in range areas than in urban areas (p equals 0.01). Ammonia concentrations in the deep aquifers were not significantly different for urban and range areas (p greater than 0.05; fig. 57). Nitrate concentrations in ground

water from deep wells in urban and range areas (fig. 57) were not significantly different (p greater than 0.05).

Relation of Well Depth to Nutrient Concentration

Nutrient concentrations, as previously discussed, can be affected by land use. Because land use is a surface activity, well depth (or alternatively, the depth a water sample was collected) can have a relation to nutrient concentrations.

In agricultural areas, dissolved orthophosphate concentrations (fig. 54) in water samples from shallow aquifers (50 ft or less) were significantly (p less than 0.01) higher (median, 0.22 mg/L as P) than those from deep aquifers (median, 0.05 mg/L as P).

All other land uses had medians (0.03 to 0.04 mg/L as P) of orthophosphate that were not significantly different (p greater than 0.05), indicating no effects on these concentrations because of the depth of the well.

In urban and range areas, dissolved ammonia concentrations (fig. 54) in water samples from shallow aquifers had significantly (p less than 0.01) higher medians (0.10 and 0.08 mg/L as N, respectively) than those from deep aquifers (medians, 0.01 mg/L as N). In other land-use categories, concentrations were not significantly (p greater than 0.05) different in water samples from shallow and deep aquifers.

In urban and agricultural areas, dissolved nitrate concentrations (fig. 54) in water samples from shallow aquifers were significantly (p less than 0.01 and equal to 0.04, respectively) higher (medians, 2.8 and 0.46 mg/L as N, respectively) than those from the deep aquifers (0.37 and 0.13 mg/L, respectively). Nitrate concentrations were not significantly different (p greater than 0.05) in deep and shallow aquifers in range and wetland areas.

NITRATE CONCENTRATIONS IN GROUND WATER AND NEVADA STATE DRINKING-WATER STANDARDS

Of the nutrients discussed in this report, nitrate is the only one that has a primary drinking-water standard (maximum contaminant level, MCL) that is enforceable in the State of Nevada. The State has adopted the Federal standard of 10 mg/L as N (equivalent to 44 mg/L as NO_3) for nitrate concentrations in drinking water. Nitrate, in high concentrations, can be toxic to humans, especially infants. "Blue-baby" syndrome in infants is the most common effect of high nitrate concentrations. Potential sources of nitrate in ground water include exfiltration of sewage from leaking sewer pipes, infiltration from applied sewage effluent, leaching of nitrate from areas where solid sewage or sludge has been applied, leaking or improperly functioning septic systems, applied fertilizer, and natural nitrogen-containing salts or organic matter. Any one or combination of the above sources can be responsible for elevated nitrate concentrations in ground water at a certain location. Without a detailed study at each location with high nitrate values, the exact source of the nitrate cannot be determined.

Of the 363 wells where samples were collected for nitrate analyses, samples from only 14 wells exceeded the MCL for nitrate. Many other nitrate analyses had values greater than the MCL, but these were

not included in the data set analyzed for this report because of the unknown accuracy of these values (see section in this chapter entitled "Previous Studies"). Six of the samples exceeding the MCL (range from 11 to 27 mg/L) were from the Las Vegas Valley and eight (range from 10 to 20 mg/L) were from the Carson River Basin.

In the Las Vegas Valley area, all of the high-nitrate samples were obtained from wells in the Whitney area, southeast of Las Vegas and northwest of Henderson, and were in the range land-use categories. Emme and Prudic (1991) indicate that all the samples from the Whitney area southeast of Las Vegas with high nitrate concentrations were from wells near sewage ditches or areas where sewage sludge was applied (wells 73, 75, 97, 102, 103, and 113 on pl. 1).

Four of the wells with high nitrate concentrations are in the Carson City urban area within Eagle Valley (wells 267, 273, 297, and 311 on pl. 2). Possible sources for these high nitrate concentrations that included leaking sewer pipes and nitrogen-based fertilizer application were reported by Lawrence (1996). These wells are within urban land-use areas and, thus, are subject to the effects of many anthropogenic activities. Two domestic wells in the Carson River Basin with high nitrate concentrations are in an area where 1-acre homesites are serviced by individual water and septic systems (wells 322 and 323 on pl. 2). In this area, domestic wells are in close proximity to septic systems, resulting in a high potential for contamination of drinking water. Two of the samples from the Carson River Basin are from domestic wells in the Carson Desert agricultural land-use area (wells 168 and 204 on pl. 2). Nitrogen-based fertilizer is a possible source of the high nitrate concentrations, but septic systems cannot be ruled out because of their commonly close proximity to domestic wells.

Several settings within the study area have the potential for nitrate contamination of shallow drinking-water supplies. Areas within the study unit have high densities of septic systems interspersed with domestic wells. These areas are where most of the known nitrate contamination is found. Carson City is requiring the abandonment of septic systems in parts of the city because of nitrate contamination of private domestic-supply wells (Vector Engineering, 1993). Many of these areas will rely on deeper public-supply wells for water in the future. The increased use of reclaimed waste water for irrigation can increase the potential for contamination of shallow ground water in these areas. Golf courses, parks, pasture, and alfalfa fields are

irrigated in Las Vegas Valley and Carson River Basin with treated sewage effluent. Many other areas, especially in Las Vegas Valley, dispose of treated sewage sludge by spreading it on the ground.

In parts of some urban areas, such as Las Vegas, Carson City, and Reno, old sewer pipes could be leaking effluent into the shallow ground-water aquifers. Such exfiltration of untreated sewage may take place for years before the leak is discovered and repaired, thus contaminating large areas of the shallow aquifers.

Fertilizers are another possible source of nitrate, ammonia, and orthophosphate contamination of shallow ground water. Both agricultural and urban settings commonly have fertilizers applied to either crop or lawn areas. The most abundant crop in Nevada, alfalfa, is not usually fertilized with nitrogen-based compounds. Being a legume, alfalfa fixes nitrogen from the atmosphere and can be a source of nitrate to the ground water. However, pastures and parks are fertilized.

Homeowners and golf-course maintenance workers commonly apply fertilizers (mainly ammonium sulfate and ammonium phosphate) to lawns. Irrigation in these areas can leach fertilizers into shallow ground water.

Natural sources of nitrate can cause ground water to approach or exceed MCL values. Nitrogen is an essential element in all living matter, and thus, organic-rich sedimentary deposits can contain substantial quantities of nitrogen. If these deposits are oxidized by oxygen-rich ground water, nitrate concentrations can approach or exceed the MCL. One area within the NVBR NAWQA study unit has been described where natural sources of nitrate are contaminating the ground water. This area is northwest of Las Vegas in an area known as Gilcrease Ranch. Patt and Hess (1976) and Hess and Patt (1977) attribute high nitrate concentrations in this area to natural organic or evaporite components of the sediment.

PESTICIDES IN SURFACE AND GROUND WATER

by Kathryn C. Kilroy

INTRODUCTION

Pesticides are considered a threat to the Nation's water resources because of their effects on a wide variety of non-target species, particularly aquatic organisms and vertebrates. Pesticides can be toxic, carcinogenic, teratogenic, and can lower reproduction rates. In addition, some environmentally persistent pesticides tend to bioaccumulate in the food chain, a few may contain undesirable byproducts as impurities, and a few are metabolized to more lethal compounds under certain conditions. The carcinogenic and teratogenic properties of pesticides are of greatest concern for human health; however, toxicity and lowered reproductive rates are of most concern for aquatic organisms.

Purpose and Scope of This Section

The purpose of this section is to evaluate pesticide data principally collected during water years 1970-90 in the NVBR NAWQA study unit. A few samples collected prior to water year 1970 or after water year 1990 are included. A summary of what is known about the areal distribution of pesticides in relation to hydrologic setting (headwater or basin areas), hydrographic area, and sampling matrix (fish, sediments, surface water, or ground water) is made and a preliminary evaluation of temporal trends in pesticide concentrations in surface water is made also. Data in this section include pesticides with reported use in the study unit and some pesticide degradation products.

Pesticide contamination of ground- and surface-water resources is a function of (1) location, quantity, and timing of pesticide use; (2) properties of the pesticide that determine its likelihood of leaching from soil, foliage, seed, or other applications; (3) characteristics of the topography, soil, unsaturated zone, or aquifer that determine the probability of a leachate moving off site; (4) the distance of the application zone from ground-water recharge zones and streams; and (5) the climate of the application zone.

This section shows the relation between pesticide use and pesticide contamination of natural waters by addressing the first two of the above-mentioned contamination elements. Elements 3, 4, and 5 above are discussed only briefly in terms of land-use categories because only limited pesticide information specific to topography, soils, aquifers, recharge-discharge, and climatic effects was available.

Previous Investigations

Water-quality data were collected by Federal, State, and local agencies to facilitate management of water resources in the study unit. A wide variety of matrices were sampled at a limited number of sites. The limited number of sample sites may, in part, reflect the expense of sampling for pesticides, the limited use of agricultural pesticides within the study area, and the absence of an indication that a serious problem may be present. The discussion that follows is organized according to matrix sampled—surface water, fish tissue, bottom sediments, and ground water—not according to area because so many of the studies crossed these boundaries. An inventory of available pesticide data for the Nevada Basin and Range study unit is presented in table 10. The table includes State and Federal agencies and information on sampling protocols, period of record, number of sites, collecting agency, and matrix sampled. Study sites are referenced to plates 1 and 2 and appendix A.

Surface Water

A surface-water network, the National Water-Quality Stream Surveillance (NQWSS) Program, for which pesticides were studied, was operated by USGS (study A, table 11). The data are stored in QWDATA1, a computerized data base maintained by USGS, but are not published. The NQWSS includes one site on Las Vegas Wash near Boulder City (site 18, pl. 1 and app. A), and two sites on the Truckee River (Farad and Lockwood, sites 138 and 158, pl. 2 and app. A). The samples were analyzed by gas chromatography and detection limits ranged from 0.01 to 1.0 µg/L. Twenty-four pesticides were analyzed for during the late 1970's. Only 2,4-D; 2,4,5-T; 2,4,5-TP; aldrin; γ -BHC; *p,p'*-DDD; *p,p'*-DDE; diazinon; dieldrin; endosulfan; lindane; and malathion were detected.

Table 10. Inventory of available pesticide data for Nevada Basin and Range NAWQA study unit

Sampling purpose: L, long-term monitoring; R, regulatory monitoring; S, synoptic monitoring.

Sampling frequency: A, annual; I, irregular, less than once per year; L, long term; O, one time only.

Sampling method: G, gas chromatography; U, USGS techniques; X, unknown; Z, 3-6 whole adult fish sampled, prepared with Na₂SO₄, dichloromethane, hexane, and petroleum ether, and extracted by gas and liquid chromatography and mass spectroscopy as per Schmitt and others (1985).

Sampling matrix: B, bottom sediments, F, fish tissue; T, unfiltered water; and W, water filtered through 0.45 micrometer.

Record status: C, data are on USGS Nevada District Prime computer in QWDATA 1 database; F, paper copy or microfiche; P, data are published; T, data on magnetic tape or diskette.

Number and type of sites: EF, treated sewage effluent; GW, ground water; SW, surface water.

[--, unknown or not available.]

Sampling				Period of record	Record status	Number and type of sites	Notes
Purpose	Frequency	Method	Matrix				
STATE AGENCIES							
California							
S	I	G	T	--	F	--	California Department of Food and Agriculture, Pest Management, Environmental Management, and Worker Safety. All pesticide monitoring and files have been transferred to California Environmental Protection Agency.
R	A	G	T	1967-	F	--	California Department of Health Services, Office of Drinking Water.
California Environmental Protection Agency							
L, S	L	G	T	1971-	P, T	--	Department of Pesticide Regulation, Branch of Environmental Monitoring. Manages Well Inventory Data Base. Annual reports for 1986-91.
L, S	A	G	F	1978-87	P	4 SW	California Water Quality Control Board, Lahontan District Toxic Substances Monitoring Program. Data for Carson and Truckee River Basins in California. Reported by Rasmussen and Blethrow (1990).
Nevada							
S	A	G	T	1990-92	F	--	Nevada Department of Business and Industry, Division of Agriculture, State Management Plan. Five-year program began in 1990. Pesticide-use data available since 1982.
--	--	--	T	1980's	F	--	Nevada Department of Conservation and Natural Resources, Division of Environmental Protection, Bureau of Water-Quality Planning.
--	--	--	T	1980's	F	--	Nevada Department of Conservation and Natural Resources, Hazardous Waste Division.
R	A	G	T	1972-92	F	10 GW	Nevada Department of Human Resources.
--	--	--	--	--	--	20 SW	Nevada Department of Human Resources, Health Division, Bureau of Consumer Health Protection Services.

Table 10. Inventory of available pesticide data for Nevada Basin and Range NAWQA study unit—Continued

Sampling				Number			
Purpose	Frequency	Method	Matrix	Period	Record	of sites	Notes
				of record	status	and matrix samples	
FEDERAL AGENCIES							
--	--	--	T	--	F	--	Agricultural Research Service.
					U.S. Department of the Interior		
--	--	--	T	1985-86	P	10 SW	Lahontan Basin Mid-Pacific Region.
						6 GW	Fallon Indian Reservation study.
S	O	X	T	1983	P	13 SW	Engineering and Research Center, from Roline and Sartoris (1984).
L	O	Z	F	1970-91	P	2 SW	U.S. Fish and Wildlife Service
						National Pesticide Monitoring Program. Data from Schmitt and others (1985). Sites on Truckee River and Lake Mead.	
L	O	--	--	--	--	--	National Park Service
						Lake Mead.	
S	I	--	T	1968-72	C, P	1 SW	U.S. Geological Survey
						Irrigation Network, later became National Stream-Quality Accounting Network, station 10312000.	
S	I	--	T	1968-82	C, P	1 SW	National Pesticide Water Monitoring Program, later became National Stream-Quality Accounting Network station 10351700.
S	I	--	T	1974-78	C, P	3 SW	National Water-Quality Stream Surveillance Program stations 09419800, 10346000, and 10350050.
S	O	--	B, T	1975-91	C, P	2 SW	National Stream-Quality Accounting Network stations 10312000, and 10351700. Survey of organic materials in bottom sediments was made in 1983.
S	O	U	B	1980	C, P	18 SW	Truckee River Water-Quality Assessment sites. Pesticide data were collected but not published.
S	O	U	T	1987	C	20 GW	Las Vegas Wash salinity study. Sampled in Whitney area in southeast Las Vegas Valley.
L, S	I	U	W	1987-89	C, P	77 GW	National Water-Quality Assessment pilot program. Sampled in the Carson River Basin.
S	I	--	W	1987-89	C, P	5 GW	Nevada Carbonate Aquifer Study pilot program. Sampled springs in the Spring Mountains and Sheep Ranges.
S	O	--	B, F, W	1986-87	C, P	24 SW	U.S. Department of Interior irrigation drainage Study. Data from Hoffman and others (1990), Rowe and others (1991), and Lico (1992).
--	--	--	W	1980-92	T	--	U.S. Environmental Protection Agency
						STORET water-quality data base.	
R, S	O	X	W	1966	F	103 SW	U.S. Public Health Service
						7 EF	Colorado River Basin Water Quality-Control Project.

Table 11. Pesticides sampled for, detection limits, and detections for studies summarized in Nevada Basin and Range NAWQA study unit

Study A: U.S. Geological Survey National Water-Quality Surveillance System sites, unpublished data, surface water, Las Vegas Wash near Boulder City, Truckee River near Farad, Truckee River near Lockwood, 1973-85. **Study B:** Roline and Sartoris (1984) for Bureau of Reclamation, surface water, Las Vegas Wash area, 1983. **Study C:** U.S. Environmental Protection Agency Region IX, unpublished data, surface water, Las Vegas Wash, 1978-84. **Study D:** U.S. Geological Survey National Stream Quality Accounting Network/National Pesticides in Water Monitoring Program sites, unpublished data, surface water, Carson River at Fort Churchill, Truckee River near Nixon, 1974-83. **Study E:** U.S. Environmental Protection Agency Region IX, unpublished data, whole fish, 19 sites in Las Vegas Wash, 1978-84. **Study F:** Rasmussen and Blethrow (1990) for California Water Resources Control Board, fish filets, Stampede Reservoir and Squaw Creek, Truckee River at Farad, Gray Creek near Hirschdale, East Fork Carson River near Markleeville, 1978-89. **Study G:** Schmitt and others (1985) for U.S. Fish and Wildlife Service, whole fish, Truckee River near Fernley and Lake Mead, 1977-84. **Study H:** U.S. Environmental Protection Agency Region IX, unpublished data, bottom sediments, 21 sites in Las Vegas Wash, 1978-87. **Study I:** Hoffman and others (1990) for U.S. Geological Survey, bottom sediments, Stillwater National Wildlife Management Area, Carson Desert, 10 sites, 1987-89. **Study J:** Rowe and others (1991) for U.S. Geological Survey, bottom sediments, Stillwater National Wildlife Management Area, Carson Desert, 20 sites, 1986-87. **Study K:** U.S. Geological Survey Truckee River study (1980), unpublished data, bottom material, 19 sites, 1979-80. **Study L:** U.S. Geological Survey, unpublished work in Las Vegas Valley, ground water, 26 sites, 1987. **Study M:** Nevada Division of Environmental Protection, unpublished data, ground water, Las Vegas Valley, 1980-82. **Study N:** Lico and Seiler (1994) and Welch (1994) for U.S. Geological Survey, ground water, Carson Desert and Carson Valley, 1987-90. **Study O:** Lico and Seiler (1994) for U.S. Geological Survey, ground water, Carson Desert and Carson Valley, 1987-90. **Study P:** Lawrence (1996) for U.S. Geological Survey, ground water, Eagle Valley, 1989. **Study Q:** California Department of Health Services, ground water, Carson and Truckee River Basins, 1984 to present. **Study R:** Sertic and others (1988) for Nevada Division of Environmental Protection, ground and surface water, Fallon area, 1987. **Study S:** Nevada Bureau of Consumer Health Protection, ground and surface water, Carson and Truckee Basins, 1972 to present.

Symbols: *, detection made at or above detection limit; --, unknown, not determined, or not available

Pesticide, common name	Study																			
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	
	Surface water				Fish tissue				Bottom material				Ground water				Ground and surface water			
	Detection limit (micrograms per liter in water samples and micrograms per kilogram in bottom sediment and fish-tissue samples)																			
2,4-D	0.01*	--	--	0.1*	--	--	--	--	--	--	--	--	--	0.01*	--	0.01	--	0.1	10	
2,4-DP	--	--	--	--	--	--	--	2,500	--	--	--	--	--	.01	--	.01	--	--	--	
2,4,5-T	.1*	--	--	.1	--	--	--	--	--	--	--	--	--	.01	--	.01	--	--	--	
2,4,5-TP (silvex)	.1*	--	--	.1*	--	--	--	--	--	--	--	--	--	.01	--	.01	--	--	1.0	
acrolein	--	--	--	--	50	--	--	50	--	--	--	--	--	--	--	--	--	--	--	
alachlor	--	--	--	--	--	--	--	--	--	--	--	--	--	.1	--	.1	--	--	--	
aldicarb	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.0	--	--	
aldrin	.01*	--	10	.01	500	5	--	500*	0.1*	0.1*	0.1*	0.01*	0.01	.01	0.01	.01	.004	--	--	
ametryn	--	--	--	--	--	--	--	--	--	--	--	--	--	.1	--	.1	--	--	--	
atrazine	--	--	--	.1	--	--	--	--	--	--	--	--	--	.1	--	.1	--	.2	--	
α-BHC	--	--	--	--	5*	2	10*	10*	--	--	--	--	.01*	--	--	--	--	--	--	
β-BHC	--	--	10	--	500	10	--	--	--	--	--	--	.01*	--	--	--	--	--	--	
δ-BHC	--	--	--	--	500	5	--	--	--	--	--	--	--	--	--	--	--	--	--	
γ-BHC lindane	.01*	1.0*	10	.01	500	2*	10	500	.1*	.1*	.1*	.01*	--	.01	.01*	.01	.004	--	--	
total BHC	.01	--	--	.01*	--	2*	--	--	--	--	--	--	.01*	--	--	--	.006	--	.1	

Table 11. Pesticides sampled for, detection limits, and detections for studies summarized in Nevada Basin and Range NAWQA study unit—Continued

Pesticide, common name	Study																			
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	
	Surface water				Fish tissue				Bottom material				Ground water				Ground and surface water			
	Detection limit (micrograms per liter in water samples and micrograms per kilogram in bottom sediment and fish-tissue samples)																			
carbofuran	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.0	1.0	--	
cis chlordane	--	--	--	--	--	5	10 *	--	--	--	--	--	--	--	--	--	--	--	--	
trans chlordane	--	--	--	--	--	5	10 *	--	--	--	--	--	--	--	--	--	--	--	--	
total chlordane	0.1	--	10	1.0 *	500	5	--	500	1.0 *	1.0 *	1.0 *	0.1	--	0.1	0.1	0.1	.014	--	--	
chlorpyrifos	--	--	--	--	--	10	--	--	--	--	--	--	--	--	--	--	--	--	--	
cyanazine	--	--	--	--	--	--	--	--	--	--	--	--	--	.1	--	.1	--	--	--	
p,p'-DDD	.01*	--	10	.01*	10*	10	10*	10*	.1*	.1*	.1*	.01	--	.01	.01*	.01	.011	--	--	
p,p'-DDE	.01*	--	10	.01*	10*	5	10*	10*	.1*	.1*	.1*	.01*	0.01	.01	.01	.01	.004	--	--	
DDT	--	--	--	--	500	10	10*	10	--	--	.1*	--	--	--	--	--	--	--	--	
total DDT	.01	--	10	.01*	--	5*	--	--	.1*	.1	--	.01*	--	.01	.01	.01	.012	--	--	
dacthal (DCPA)	--	--	--	--	--	5	10*	--	--	--	--	--	--	--	--	--	--	--	--	
demeton	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.1	--	--	
diazinon	.01*	--	--	.1*	--	50	--	--	--	--	--	.01*	--	--	--	.01	--	--	--	
dicamba	--	--	--	--	--	5	--	--	--	--	--	--	--	.01*	--	.01	--	--	--	
dicofol	--	--	--	--	--	100	--	--	--	--	--	--	--	--	--	--	--	--	--	
dieldrin	.01*	--	10	.01	500	5	10*	10*	.1*	.1	--	.01	--	.01	.01*	.01	.002	--	--	
dimethoate	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.2	--	
endosulfan I	--	--	--	--	500	5	--	10*	--	--	--	--	--	--	--	--	--	--	--	
endosulfan II	--	--	10	--	500	70	--	10*	--	--	--	--	--	--	--	--	--	--	--	
endosulfan sulfate	--	--	10	--	500	--	--	10*	--	--	--	--	--	--	--	--	.066	--	--	
total endosulfan	.01*	--	--	--	--	5	--	--	.1	.1	.1*	.01*	--	.01	.01	.01	.004	--	--	
endrin	.01	--	10	.01*	500	15	10*	10*	.1	.1	.1	.01	--	.01	.01*	.01	.006	--	--	
endrin aldehyde	--	--	10	--	2,500	--	--	500	--	--	--	--	--	--	--	--	.023	--	--	
ethion	.1	--	--	.01	--	--	--	--	--	--	--	.01	--	--	--	.01	--	--	--	
glyphosate	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.0	--	--	
heptachlor	.01	--	10	.01*	500	5	10	10*	.1*	.1	.1*	.01	--	.01	.01*	.01	.003	--	--	
heptachlor epoxide	.01	--	10	.01	500	5	10	10*	.1*	.1	.1	.01	--	.01	.01*	.01	.083	--	--	
HCB	--	1.0*	50	--	2,500	2	10	2,500	--	--	--	--	--	.0	--	5.0	1.9	--	--	
malathion	.1*	--	--	.1	--	--	--	--	--	--	--	.01	--	--	--	.01	--	.2	--	
methomyl	--	--	--	--	--	--	--	--	--	--	--	--	--	.5	--	.5	--	--	--	

Table 11. Pesticides sampled for, detection limits, and detections for studies summarized in Nevada Basin and Range NAWQA study unit—Continued

Pesticide, common name	Study																			
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	
	Surface water				Fish tissue				Bottom material				Ground water						Ground and surface water	
	Detection limit (micrograms per liter in water samples and micrograms per kilogram in bottom sediment and fish-tissue samples)																			
methoxychlor	--	--	--	0.1	--	15	10	10 *	0.1 *	0.1	0.1	0.01	--	0.01	0.01	0.01	10	--	1.0	
methyl parathion	0.1	--	--	.1	--	--	--	--	--	--	--	.01	--	--	--	.01	--	.2	--	
methyl trithion	.1	--	--	.1	--	--	--	--	--	--	--	.01	--	--	--	.01	--	--	--	
metolachlor	--	--	--	--	--	--	--	--	--	--	--	--	--	.1	--	.1	--	--	--	
metribuzin	--	--	--	--	--	--	--	--	--	--	--	--	--	.1	--	.1	--	--	--	
mirex	--	--	--	--	--	--	10	--	.1	.1	.1	.01	--	.01	--	.01	--	--	--	
cis nonachlor	--	--	--	--	--	5	10 *	--	--	--	--	--	--	--	--	--	--	--	--	
trans nonachlor	--	--	--	--	--	5	10 *	--	--	--	--	--	--	--	--	--	--	--	--	
oxychlordan	--	--	--	--	--	5	10	--	--	--	--	--	--	--	--	--	--	--	--	
parathion	.1	--	--	.1	--	--	--	--	--	--	--	.01	--	--	--	.01	--	--	--	
perthane	.1	--	--	--	--	--	--	--	1.0	1.0	--	.1	--	.1	0.1	.1	--	--	--	
phosmet	--	--	--	--	--	--	--	--	--	--	--	--	1.0	--	--	--	--	--	--	
picloram	--	--	--	--	--	--	--	--	--	--	--	--	--	.01	--	.01	--	--	--	
prometon	--	--	--	--	--	--	--	--	--	--	--	--	--	.1 *	--	.1 *	--	--	--	
prometryn	--	--	--	--	--	--	--	--	--	--	--	--	--	.1	--	.1	--	--	--	
propazine	--	--	--	--	--	--	--	--	--	--	--	--	--	.1	--	.1	--	--	--	
propham	--	--	--	--	--	--	--	--	--	--	--	--	--	.5	--	.5	--	--	--	
sevin	--	--	--	--	--	--	--	--	--	--	--	--	--	.5	--	.5	--	--	--	
simazine	--	--	--	.1	--	--	--	--	--	--	--	--	--	.1 *	--	.1	.06	--	--	
simetryn	--	--	--	--	--	--	--	--	--	--	--	--	--	.1	--	.1	--	--	--	
toxaphene	1.0	--	10	1.0	500	100	100 *	100 *	10.0	10.0	1.0	1.0	--	1.0	1.0	1.0	.24	--	5.0	
trifluralin	--	--	--	--	--	--	--	--	--	--	--	--	--	.1	--	.1	--	--	--	
trithion	.1	--	--	.1	--	--	--	--	--	--	--	.01	1.0	--	--	.01	--	--	--	

A study by Roline and Sartoris (1984) was done near Las Vegas Wash (study B, table 11). They sampled for the fungicide hexachlorobenzene (HCB), and the insecticide hexachlorocyclohexane (γ -BHC, lindane). Concentrations of γ -BHC and HCB were detected at a drainage ditch at Pabco Road (site 10, pl. 1 and app. A) and Alpha ditch at Boulder Highway (site 16); both ditches drain an industrial area south of Las Vegas Wash near Henderson. They concluded that γ -BHC concentrations were below levels known to be toxic to plants, that the anaerobic conditions in a marsh (no longer present) were likely to cause remediation of the γ -BHC, and that HCB was present in levels below those requiring action by the USEPA.

USEPA personnel studied pesticides found in water in Las Vegas Wash between 1978 and 1984 (study C, table 11). Information on the method of analysis used has not been ascertained. Detection limits ranged from 10 to 50 $\mu\text{g/L}$ for 18 compounds that were analyzed for and none were detected.

The National Stream-Quality Accounting Network (NASQAN) and National Pesticides in Water Monitoring Program (NPWMP) of the USGS (study D, table 11) included sampling at the Carson River near Fort Churchill (site 46, pl. 2 and app. A) and at the Truckee River near Nixon (site 171). Twenty-six contaminants were analyzed for by gas chromatography. Detection limits ranged from 0.01 to 1.0 $\mu\text{g/L}$. The analyses detected 2,4-D, γ -BHC, chlordane, *p,p'*-DDD, *p,p'*-DDE, *p,p'*-DDT, diazinon, endrin, heptachlor, and sevin.

Fish Tissue

USEPA personnel studied pesticides in fish tissues in Las Vegas Wash between 1978 and 1984 (study E, table 11). Information about the analysis method used has not been ascertained. Detection limits ranged from 5 to 2,500 $\mu\text{g/kg}$ for 22 compounds that were analyzed for and only α -BHC, *p,p'*-DDD, and *p,p'*-DDE were detected.

Rasmussen and Blethrow (1990) studied pesticide residues in fish from four sites in the Carson and Truckee River Basins during 1978-89 (study F, table 11). In that study, wet fish filets and fish lipids were analyzed by using gas chromatography. Detection limits ranged from 2 to 100 $\mu\text{g/kg}$, but averaged 5 $\mu\text{g/kg}$ for most compounds. They analyzed for 40 compounds and detected γ -BHC, *p,p'*-DDE, and *p,p'*-DDT. Rasmussen and Blethrow concluded that little pesticide

contamination was evident in the Carson and Truckee Rivers in California. No new data were collected by this study during 1989-92.

The U.S. Fish and Wildlife Service began a nationwide study in 1976 to measure organochlorine pesticide residues in fish (study G, table 11). Two study sites are located within the State of Nevada—Lake Mead (site 21, pl. 1 and app. A) and Truckee River near Fernley (site 168, pl. 2 and app. A). Schmitt and others (1985) used three to five whole adult fish for samples at each site including bottom-feeding and predator species. Analyses were done at the Columbia National Fisheries Research Laboratory using electron-capture gas chromatography. Detection limits ranged from 10 to 100 $\mu\text{g/kg}$. They found α -BHC, *p,p'*-DDD, *p,p'*-DDE, and *trans*-nonachlor. They concluded that *p,p'*-DDE was the most persistent *p,p'*-DDT homologue (*p,p'*-DDT and its degradation products *p,p'*-DDD and *p,p'*-DDE), and that *p,p'*-DDT homologues were declining nationwide.

Bottom Sediments

USEPA personnel studied pesticides in bottom sediments at 21 sites in Las Vegas Wash during 1978-87 (study H, table 11). Methods of analysis used have not been ascertained. Detection limits ranged from 500 to 2,500 $\mu\text{g/kg}$ before 1980, but some limits were lowered to 5 $\mu\text{g/kg}$ in the early 1980's. The lower detection limits are shown in table 11. In analyses for 23 compounds, aldrin, α -BHC, *p,p'*-DDD, *p,p'*-DDE, dieldrin, endosulfan I and II, endosulfan sulfate, endrin, heptachlor, heptachlor epoxide, methoxychlor, and toxaphene were detected.

Hoffman and others (1990) studied the presence of organochlorine pesticides in bottom sediments at 18 sites in the Carson Desert, the terminus of the Carson River (study I, table 11). They sampled bottom sediments sieved to less than 63- μm particle size (silt and finer). The samples were analyzed by gas chromatography and detection limits ranged from 0.1 to 10 $\mu\text{g/kg}$. Aldrin, chlordane, *p,p'*-DDD, *p,p'*-DDE, *p,p'*-DDT, dieldrin, heptachlor, heptachlor epoxide, lindane, and methoxychlor were detected. Hoffman and others (1990) concluded that *p,p'*-DDT and its degradation products were the most commonly detected pesticides, that only lindane was detected in quantities exceeding the sediment quality criteria set by the USEPA for the protection of fish and wildlife, and that with the

possible exception of lindane—these manufactured compounds are not an immediate threat to fish and wildlife in the area.

Rowe and others (1991; study J, table 11) added to the data collected by Hoffman and others (1990) in the Carson Desert area of the Carson River Basin. The same analytical techniques, analyses, and detection limits for the earlier study were used, but samples were collected from a larger area (two new surface-water sites) and analysis for toxaphene was added. Aldrin, chlordane, *p,p'*-DDD, *p,p'*-DDE, and lindane were detected.

USGS personnel studied pesticides in bottom sediments at 19 sites on the Truckee River in 1980 following detection of a PCB spill in the Truckee Canyon Segment (study K, table 11). Analysis was by gas chromatography and detection limits ranged from 0.1 to 1.0 µg/kg. Aldrin, chlordane, *p,p'*-DDD, *p,p'*-DDE, *p,p'*-DDT, endosulfan, heptachlor, and lindane were detected.

Ground Water

A study of ground-water quality in the lower Las Vegas Wash area was done by USGS in cooperation with the Bureau of Reclamation (BOR) in 1987 to determine sources and loads of salinity (study L, table 11). The ground water beneath the community of Pittman, located between Henderson and lower Las Vegas Wash, also was sampled for pesticides. Twenty-four pesticides were analyzed for by gas chromatography. The detection limits ranged from 0.01 to 0.1 µg/L for all compounds except toxaphene, which was 1 µg/L. Aldrin, *p,p'*-DDE, *p,p'*-DDT, endosulfan, diazinon, and lindane were detected. The data are in QWDATA1, a USGS water-quality data base, in digital format, but have not been published.

The USEPA, in conjunction with Nevada Division of Environmental Protection (NDEP), studied ground water in Las Vegas Valley during 1980-82 (study M, table 11). Information on the method of analysis has not been ascertained. Detection limits for aldrin, α -BHC, β -BHC, *p,p'*-DDE and lindane are 0.01 µg/L; for phosmet is 1.0 µg/L. Both BHC isomers were detected. The data are in STORET, but are unpublished.

The NAWQA pilot study of ground-water conditions in the Carson River Basin sampled 14 sites in Carson Valley, 26 sites in Eagle Valley, and 22 sites in Carson Desert for pesticide residues (studies N, O, and P in table 11). Samples were analyzed by gas

chromatography, and detection limits ranged from 0.01 to 5 µg/L. The analyses detected *p,p'*-DDD, 2,4-D, dicamba, dieldrin, endrin, heptachlor, heptachlor epoxide, lindane, prometon, and simazine in ground water. The findings of these studies are presented by Lico and Seiler (1994), Welch (1994), and Lawrence (1996).

The California Department of Health Services (CDHS) analyzes for pesticides in public water supplies in headwater areas of the Carson and Truckee River Basins under the provisions of the Safe Drinking Water Act (study Q, table 11). Sampling for pesticides has continued at approximately 1-year intervals since 1984. Analyses have detection limits ranging from 0.002 to 1.18 µg/L. No pesticides have been detected within the study unit. The data are available from the California Department of Pesticide Regulation in digital format.

Sertic and others (1988) of the Nevada Division of Environmental Protection sampled for pesticide residues at four surface-water sites and one ground-water site in the Fallon area during 1987 (study R, table 11). The sites were associated with an area used in the 1970's for disposing of pesticide containers. Sertic and others (1988) used gas chromatography and mass spectroscopy methods. The detection limits ranged from 0.1 to 1.0 µg/L. They analyzed for 2,4-D, atrazine, carbosulfan, dimethoate, ethyl parathion, malathion, and methyl parathion, but detected no pesticide residues at any of the sites.

The Nevada Bureau of Consumer Health Protection (NBCHP) tests for pesticides in public water supplies under the provisions of the Safe Drinking Water Act (study S, table 11). Sampling for pesticides has continued at approximately 3-year intervals since 1972. Only surface- and ground-water resources in agricultural areas are sampled. Samples were collected at the source or well head, but now are more frequently collected at the faucet or somewhere within the distribution system. Analysis is by gas chromatography. Sampling done in 1972 included chlordane, *p,p'*-DDT, dieldrin, endrin, heptachlor, heptachlor epoxide, and lindane. Heptachlor epoxide and *p,p'*-DDT were detected, but the detection limits were not recorded. A suite of six pesticides have been analyzed for since 1972, including 2,4-D, endrin, lindane, methoxychlor, silvex, and toxaphene; none have been found within the study area. The detection limits range from 0.1 to 10 µg/L. The data are available at NBCHP offices in Carson City, Nev.

Other Studies

The U.S. Public Health Service (1967) analyzed samples from 16 surface-water sites in Las Vegas Wash, Las Vegas Bay, and nearby sewage discharge in 1966 for the pesticides *p,p'*-DDT, dieldrin, and endrin. The report does not describe sampling methods, analytical methods, or detection limits; however, detection limits appear to be 10 µg/L for dieldrin, and 100 µg/L for *p,p'*-DDT and endrin. The compound *p,p'*-DDT was detected at all 16 sites, dieldrin was detected in trace amounts at 13 sites, and endrin was detected in trace amounts at 11 sites. Personnel from the study concluded that no excessive concentrations of any pesticides were detected in the evaporation ponds, Las Vegas Wash, or Las Vegas Bay, and that all concentrations were below the level of concern. The results of that study were not listed in table 11 because the date of sampling precedes the time frame of this study, and sampling methods have not been ascertained.

Limitations of Data

The purposes for sampling, matrices sampled, methods of analyses, and detection limits used for the studies discussed above differ greatly. Sampling purposes are the result of diverse objectives such as monitoring for compliance with regulations (safe drinking-water standards, landfills, and hazardous-waste sites) and conducting research on specific water-quality issues (urban pesticide use, and irrigation return flow to wildlife-management areas). Sampled matrices include surface water, fish tissue, bottom sediments, and ground water. Gas chromatography was the most common method of analysis, but solvents used to wash the samples through chromatograph columns caused detection limits to differ by five orders of magnitude. The different methods of collection, preservation, and analysis severely limit the interpretations that can be made from the data.

Field collection, sample-preservation, and laboratory analytical methods for pesticides were different for each study. Therefore, comparing values between studies or making statistical inferences based on quantitative information is not possible. Qualitative comparisons of pesticide data are made to address pesticide issues in the study unit. The reader is cautioned not to read more into the value of the pesticide data than the variable quality warrant. For temporal analyses,

only data collected by a single agency were used for any one site, so that the problem of mixing sampling methods was generally avoided.

Available data were evaluated with respect to areas within the study unit, hydrologic settings, type of matrix sampled, and type of pesticide analysis used. Data were analyzed only with respect to the frequency of detections in each area or sampled matrix.

PESTICIDE CHARACTERISTICS AND PROPERTIES

Pesticide nomenclature tends to be excessive and convoluted because different names are used for each compound and formulation. Some pesticide formulations also include additional chemicals that may have deleterious effects of their own. The effects of pesticides in the hydrologic environment result from chemical and physical properties, which control their presence and their toxicity.

Pesticides are marketed under different trade names. This report avoids trade names and chemical formulas in favor of common names, except where acronyms and trade names are accepted as common names.

Four broad usage categories are discussed—herbicides, insecticides, fungicides, and rodenticides. Subdivisions of these usage categories are based on chemical, functional-group, structural, or attributional characteristics of the compounds. Some chemical groups (carbamates and organophosphates) are used for a variety of pesticides (herbicides, insecticides, and fungicides); whereas some have specific applications (such as rodenticides). Most groups have not been sampled for at all in the study unit, and only a few (acid amides, chlorinated phenoxy acids, organophosphates, cyclodienes, and triazine herbicides) have been tested for extensively.

Environmental Characteristics

The physical and chemical properties of pesticides exert important controls on their eventual fate within the environment. Pesticides migrate from the site of application by dissolution and transport in ground and surface water, adsorption to soil particles and humus constituents that are transported by wind and water, volatilization and adsorption to aerosol particles, and by food-chain processes in humans and animals.

Soluble materials tend to dissolve and dilute quickly, but some may sorb onto clays. The solubility of pesticides in water is a function of polarity and may differ from less than 1 part per million to miscible in all proportions. Most pesticides sampled for in the study area are insoluble or only slightly soluble in water (Verschuren, 1983). As a group, the herbicides are more soluble than insecticides.

Compounds not readily soluble in water tend to be nonpolar compounds that are adsorbed by humic constituents and accumulated in fatty tissues of animals. Most of the pesticides detected in the study unit are nonpolar compounds.

Organic compounds having large vapor pressures volatilize more readily than those with small vapor pressures. Most of the pesticides detected in the study unit have small vapor pressures. Those with a large vapor pressure are usually sold as fumigants. Hydrophobic organic compounds are more likely to volatilize from water than from soil.

Toxic Properties

The toxic properties of pesticides are of concern. Twenty-two of the pesticides used in the study unit (12 percent) are now discontinued and nearly one-half are restricted in use because of environmental concerns. Table 12 lists some toxic properties for pesticides detected in surface and ground water in the study unit, including USEPA Maximum Contaminant Levels (MCL) for drinking water, toxicity classes based on lethal-dose estimates in rats (LD50), USEPA and National Academy of Sciences (NAS) water-quality criteria for chronic exposure of freshwater aquatic organisms, sensitive-animal classes, and USEPA cancer groups (U.S. Environmental Protection Agency, 1992).

Most of the pesticides detected during the studies were at concentrations below the MCL's even though sediments and fish tissue tend to accumulate pesticides. No herbicide concentrations exceeded the MCL's, but the insecticides chlordane, endrin, heptachlor, lindane, and toxaphene, and the degradation product heptachlor epoxide were detected in concentrations that meet or exceed the MCL's. All detections were below the toxicity class levels determined from lethal-dose tests on rats.

Many of the same detected pesticides that exceeded MCL's were above the NAS water-quality criteria, including aldrin, chlordane, *p,p'*-DDD,

p,p'-DDT, diazinon, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, lindane, malathion, and toxaphene. Fish are the most commonly affected animal class, followed by birds and bees.

PESTICIDE USE

Information on pesticide use in Nevada has been compiled (table 13). The pesticides that were used, the quantity used, and when they were used are summarized. The principal sources of information on pesticide use are the Nevada Agricultural Statistics Service, from which agricultural uses were determined; the Nevada Division of Agriculture, from which many non-crop uses were determined; and retail outlets, from which urban uses were determined.

The pesticide-use information is somewhat non-specific and incomplete because systematic records have been kept in only a few areas for a short time. Most of the data are available only as summaries of statewide applications. Nevertheless, most of the pesticide usage categories are represented within the study area. Usage within the part of the study area in California is assumed to be similar to that for comparable land uses in Nevada, particularly because there is no agriculture (except grazing) in that part of the study area. Both the type and quantity of pesticides used may be underrepresented in table 13. Only licensed applicators are required to report usage; usage by noncommercial applicators is estimated. Pesticide use differs from year to year depending on weather conditions, insect life cycles, and market and economic factors. Also, usage information is limited for pesticides that were banned or discontinued during the 1960's and 1970's.

The use of approximately 190 pesticides has been reported in Nevada since 1970. Pesticide use tends to be specific for each type of land use. The major use of pesticides in Nevada is for agriculture. Urban use is secondary and remote use (including road sides and campgrounds) is negligible. Point-source industrial sites, where pesticides are manufactured or disposed of, can also be sources of pesticides to the environment.

Agricultural Areas

The major crops in Nevada are hay and pasture; cereal crops are of secondary importance, and bulb, tuber, and other crops are minor (Nevada Division of Agriculture, 1982-91; Sorenson and DeWitt, 1991). The major agricultural concerns are broadleaf weeds

Table 12. Characteristics related to toxicity for selected pesticides detected in surface- and ground-water samples in Nevada Basin and Range study unit. Modified from Verschueren (1983), Holden (1986), U.S. Environmental Protection Agency (1992), and Meister (1994)

Maximum contaminant level: For municipal or domestic supply drinking water determined by U.S. Environmental Protection Agency.

Toxicity class: Toxicity classes indicate ranges of oral LD50's (Lethal Dose to 50 percent of population) for rats. Class I, highly toxic—labeled "Danger" or "Poison" (<50 mg/kg); class II, moderately toxic—labeled "Warning" (50-500 mg/kg); class III, modestly toxic—labeled "Caution" (500-5,000 mg/kg); and class IV, slightly toxic—labeled "Caution" (>5,000 mg/kg). Letter "A" refers to chemicals recognized by National Academy of Sciences as potential threats to predator aquatic species when occurring in combination.

Water-quality criteria: For chronic exposure to freshwater aquatic organisms; from U.S. Environmental Protection Agency (EPA) and National Academy of Sciences (NAS).

Sensitive animal classes: A, birds; B, bees; F, fish; and M, mammals.

Cancer group: U.S. Environmental Protection Agency classifications: B2, insufficient evidence in humans but sufficient evidence in animals; C, possibly carcinogenic to humans; D, not classified as to human carcinogenicity; U, classification is under review.

[--, not applicable or available]

Pesticide	Maximum contaminant level (milligrams per kilogram)	Toxicity class	Water-quality criteria		Sensitive animal classes	Cancer group
			EPA (micrograms per liter)	NAS (micrograms per liter)		
Herbicides						
2,4-D	0.07	I	3	--	--	D
2,4,5-T	--	III	--	--	--	--
2,4,5-TP (Silvex)	.05	III	--	--	--	--
Dacthal (DCPA)	--	IV	--	--	--	D
Dicamba	--	III	200	--	--	D
Prometon	--	--	--	--	F	D
Simazine	.004	IV	10	--	--	C
Insecticides						
Aldrin	--	IA	--	0.01	F	B2
γ BHC (Lindane)	--	II	.08	.02	--	B2, U
Chlordane	.002	II	.0043	.04	B,F	B2
<i>p,p'</i> -DDT	--	II	.001	2.0	F	B2
Diazinon	--	II	--	.009	B,F	D
Dieldrin	--	IA	.0019	.005	B,F	B2
Endosulfan	--	IA	.056	.003	A,B,F	--
Endrin	.002	IA	.0023	.002	M	D
Heptachlor	.0004	II	.0038	.01	--	B2
Lindane	.0002	IIA	.08	.02	B,F	--
Malathion	--	III	.1	.006	B,F	D
Methoxychlor	.040	IV	.03	.005	--	D
Toxaphene	.003	IA	.0002	.01	F	B2
Fungicide						
HCB	--	III	--	--	M	--
Degradation byproducts						
<i>p,p'</i> -DDD	--	III	--	.006	--	--
Heptachlor epoxide	.0002	IA	.0038	--	--	--

Table 13. Major pesticides used in Nevada during 1970-91. From Nevada Department of Business and Industry, Division of Agriculture (1982-91), Sorenson and DeWitt (1991), and Meister (1994)

Agricultural and urban use: Estimates based on weight or volume information. For some, the estimates may be low due to underreporting. Density of 1 gram per milliliter was assumed in all conversions from volume to weight. T, more than 1 pound but less than 50 pounds used; M, major use, amount unspecified. Quantities shown to two significant figures. --, less than 1 pound or no use reported.

Pesticide		Agricultural use (pounds of active ingredient)					Urban use, 1991 (pounds of active ingredient)		Use restrictions
		1970's	1982	1984	1986	1988	1990	Commercial	
Herbicides									
2,4-D	M	130,000	43,000	6,000	28,000	53,000	200	--	cancelled 1980's restricted
2,4-DB	M	81,000	4,100	24,000	4,200	8,000	--	--	
2,4,5-T	T	--	100	--	--	900	T	--	
Amitrol	T	2,100	T	2,200	--	--	T	--	
Arsenal	T	--	--	2,300	200	200	T	--	
Atrazine	T	7,000	17,000	6,600	5,500	400	T	--	restricted
Benefin	T	--	--	--	100	500	--	--	cancelled 1984
Bentranil	T	--	--	--	--	500	--	--	
Bromacil	T	--	--	--	400	400	--	--	
Bromoxynil	T	100	400	700	--	300	T	--	
Carbyne	T	---	--	--	100	--	--	--	
Chlorpropham	M	200,000	110,000	10,000	500	580,000	T	--	cancelled 1980
Chlorsulfuron	T	--	--	--	--	T	--	--	
Cyanazine	T	--	--	100	--	800	T	--	
Cytex	T	6,900	--	--	--	--	--	--	
DCPA	T	--	--	5,700	--	4,000	--	--	
Dicamba	T	--	100	100	--	3,000	T	--	restricted
Diclofop-Methyl	T	--	400	100	--	1,400	--	--	
Dichlorprop	T	--	--	--	--	400	T	--	
Difenzoquat-methyl sulfate	T	800	--	--	--	2,500	--	--	
Dinoseb	T	18,000	21,000	8,700	--	--	--	--	
Diquat	T	500	800	600	7,500	400	--	--	cancelled 1991
Diuron	T	6,300	200	1,600	10,000	3,000	T	--	
Endothall	M	20,000	13,000	3,200	18,000	700	--	--	
EPTC	T	--	--	13,000	8,600	3,000	--	--	
Fluazifop-P-butyl	T	--	T	--	T	200	--	--	
Glyphosate	T	700	16,000	800	5,200	3,000	100	T	restricted
Hexazinone	T	--	8,200	27,000	21,000	7,700	T	--	
Linuron	T	--	100	--	--	--	--	--	
Maleic hydrazine	T	--	3,900	11,000	3,000	3,600	--	--	
MCPA	T	200	400	1,500	--	900	T	--	
Metolachlor	T	--	1,100	6,200	--	9,000	--	--	restricted
Metoxuron	T	--	200	--	--	--	--	--	
Metribuzin	M	18,000	8,600	25,000	6,800	8,000	--	--	
Oxyfluorofen	T	--	--	600	500	100	--	--	

Table 13. Major pesticides used in Nevada during 1970-91—Continued

Pesticide	Agricultural use (in pound of active ingredient)						Urban use 1991 (pounds of active ingredient)		Use restrictions	
	1970's	1982	1984	1986	1988	1990	Commercial	Individual		
Herbicides—Continued										
Paraquat diCl	M	8,400	5,200	4,000	7,000	800	T	--	restricted	
Pendimethalin	T	--	1,100	5,000	10,000	4,000	T	--		
Picloram	T	--	--	--	--	7,000	T	--		
Pronamide	T	--	--	18,000	--	100	--	--		
Propham	T	---	200	500	--	--	--	--		
Sethoxydim	T	--	--	1,400	T	600	--	--		
Simazine	T	2,500	500	100	17,000	16,000	T	--	restricted	
Sulfometuron methyl	T	--	100	--	400	400	100	--		
Tebuthiuron	T	700	3,400	700	2,400	--	T	--		
Terbacil	T	200	500	600	500	1,000	--	--		
Tryclopvr	T	--	--	--	400	300	T	--		
Trifluralin	T	100	--	3,000	2,400	1,000	T	--		restricted
Vernolate	T	--	--	1,000	--	--	--	--		
Fungicides, Bacteriacides, and Nematicides										
Captafol	T	1,200	--	--	--	--	--	--		
Chloropicrin	T	--	--	--	97,000	140,000	--	--		
Chlorothalonil	M	4,100	4,300	200	--	11,000	--	--		
Iprodione	T	--	--	T	--	1,000	--	--	restricted	
Mancozeb	T	5,400	11,000	--	--	--	--	--		
Maneb	M	1,600	900	24,000	28,000	2,000	--	--		
Metalaxyl	T	--	--	400	100	--	--	--		
Propiconazole	T	--	--	--	2,100	--	--	--		
Sulfur	T	700	--	--	1,700	3,100	--	--		
Zineb	T	--	11,000	--	--	--	--	--	restricted	
Rodenticides, Molluscicides, and Avicides										
Brodifacoum	T	--	--	--	--	--	100	T		
Metaldehyde	T	--	--	--	--	--	T	T		
Insecticides										
Acephate	T	--	--	--	600	--	100	T		
Azinphos methyl	T	--	T	300	T	--	--	--	restricted	
Bendiocarb	T	--	--	--	--	--	200	--		
Bifenthrin	T	--	--	2,000	--	--	--	--		
Boric acid	T	--	--	--	--	--	100	T		
Carbaryl	T	--	T	400	300	2,000	200	T		
Carbofuran	M	20,000	17,000	25,000	14,000	6,000	--	--		restricted cancelled 1987
Carbophenothion	T	--	1,800	--	---	---	--	--		
Chlorpyrifos	T	--	2,800	300	300	2,000	200	T		
Coumaphos	T	--	100	--	--	--	--	--		
Cypermethrin	T	--	--	--	100	--	200	--		
p,p'-DDT	M	--	--	--	--	--	--	--	cancelled 1973 cancelled 1989	
Demeton	T	7,500	4,100	7,600	100	200	--	--		
Diazinon	T	--	T	200	--	800	400	T		

Table 13. Major pesticides used in Nevada during 1970-91—Continued

Pesticide		Agricultural use (in pound of active ingredient)					Urban use 1991 (pounds of active ingredient)		Use restrictions
		1970's	1982	1984	1986	1988	1990	Commercial	
Insecticides—Continued									
Dicofol	T	1,100	--	500	100	800	T	--	restricted
Dimethoate	T	29,000	25,000	20,000	28,000	3,000	T	--	
Disulfoton	T	--	--	400	100	400	--	--	
Endosulfan	M	22,000	17,000	10,000	5,700	8,300	--	T	restricted
Esfenvalerate	T	--	--	--	300	--	--	--	
								--	
Fenpropathrin	T	--	--	1,000	--	--	--	--	restricted
Fenthion	T	900	400	400	700	--	--	--	
Fenvalerate	T	--	--	--	--	--	100	--	
Fluvalinate	T	--	--	--	1,900	--	--	--	
Malathion	T	7,900	8,400	22,000	1,300	1,000	T	--	
								T	
Methamidophos	T	2,000	--	600	2,600	700	T	--	restricted
Methidathion	M	6,800	6,200	18,000	4,800	700	--	--	restricted
Methomyl	T	100	1,000	--	100	--	--	--	restricted
Methoxychlor	T	--	--	700	--	--	--	--	restricted
Methyl parathion	T	4,000	3,600	5,400	11,000	200	--	T	
								--	
Mevinphos	T	800	2,600	9,300	3,200	200	--	--	restricted
Naled	M	8,000	6,200	11,000	2,600	2,900	--	--	
Oxydemeton methyl	T	1,100	2,300	600	4,200	700	--	--	
Parathion	M	13,000	10,000	17,000	2,300	1,000	--	--	
Permethrin	T	--	700	--	--	200	--	--	
								T	
Phorate	T	32,000	--	1,200	--	6,000	--	--	restricted
Phosmet	T	--	--	--	1,000	700	--	--	cancelled 1978
Piperonyl butoxide	T	--	--	500	--	--	--	--	cancelled 1991
Pirimicarb	T	500	700	700	400	--	--	T	cancelled 1982
Propargite	T	3,100	2,100	2,400	8,400	6,500	--	--	
								--	
Propoxur	T	--	--	--	100	--	T	--	cancelled 1982
Pyrethrum	T	--	--	--	--	--	200	--	
Temephos	T	--	--	--	--	--	200	T	
Thuracide	T	--	1,800	500	--	T	T	--	
Toxaphene	T	3,200	1,800	500	--	--	--	--	
Trichlorfon	T	4,100	200	2,500	--	--	--	--	
								--	

(canadian thistle, mustard, russian thistle, and willow); grassy weeds (cheatgrass, and volunteer grains); insects that affect plants (army worms, aphids, crickets, cutworms, grasshoppers, loopers, lygus, thrips, and weevils); acarids (scales, ticks, and spider mites); and insects that affect stock and humans (flies, lice, mites, and mosquitoes).

Most heavily used herbicides (greater than 30,000 lbs of active ingredient used during the 9-year period of record), reported by Nevada Division of Agriculture are 2,4-D, 2,4-DB, atrazine, chlorpropham, dinoseb, endothall, hexazinone, metribuzin, and simazine. These herbicides are primarily used for broadleaf weeds and some grassy weeds.

Principal insecticides (greater than 30,000 lbs of active ingredient) are carbofuran, dimethoate, endosulfan, malathion, methidathion, naled, and parathion. Despite the semiarid climate, mosquito abatement is important in agricultural areas; however, fungicides and nematocides (chloropicrin and maneb) are used infrequently because few tuber and bulb crops (potatoes, onions, and garlic) and no wetland crops (rice) are grown. Rodenticides (strychnine and zinc phosphide) are used sparingly for gophers.

Growers reported that approximately 30 percent of herbicides and 50 percent of insecticides were applied by aircraft (Sorenson and DeWitt, 1991); however, commercial applicators reported a much higher percentage of application by air for herbicides and insecticides (Nevada Division of Agriculture, 1982-91). Most grower applications are done by land-surface methods.

Urban Areas

Pesticides are used by commercial applicators in urban areas for lawn care, tree maintenance, and structural pest control. The major urban concerns are broadleaf and grassy weeds in turf and ornamental shrubbery; crawling insects (ants, silverfish, and cockroaches); insects that affect plants (army worms, aphids, cutworms, loopers, and weevils); subterranean insects (termites); acarids (spiders); insects that affect human health (flies, lice, and mosquitoes); and rodents. The principal herbicides (more than a trace used) include 2,4-D, glyphosate, and sulfometuron methyl, which have both selective and broad-spectrum activity. Only 2,4-D is an important herbicide to both agricultural and urban land use. The most important insecticides are acephate, bendiocarb, boric acid, carbaryl, chlorpyrifos, cypermethrin, diazinon, fenvalerate, pyrethrum, and temephos, which also have a broad spectrum of application. The rodenticide brodifacoum is the most heavily used.

Pesticides are used by noncommercial applicators in homes, lawns, and gardens for crawling and flying insects, fleas and ticks on pets, body lice, rodents, and fungi. Although the amount each individual uses can be small, the total use is considerable. Furthermore, adherence to regulations for application and disposal may be less careful, in some instances, than for commercial applicators. The list of pesticides used by

individuals is smaller than those used by commercial applicators, possibly because only nonrestricted pesticides are available for over-the-counter sales.

Remote Areas

Pesticide use in remote areas is extremely limited. Range areas are occasionally sprayed for weed and insect control. Roadsides, electrical substations, and railroad rights-of-way are sprayed to control weeds. Pesticide use in forests is limited, and currently includes only diazinon baits set out near campgrounds for fleas that harbor plague and infest rodents. Non-commercial applications are not known for remote areas.

Point-Source Industries

Pesticides generally are considered to be non-point-source contaminants; however, several point-source sites are known within the study area. Some knowledge of sites known to be underlain by contaminant plumes is necessary to discuss pesticide contamination or to plan sampling strategies.

Pesticides have been manufactured since 1948 at a facility near Henderson in Las Vegas Valley. Several chemical companies have occupied the complex and produced organochlorine and organophosphate pesticides. Lindane (γ -BHC) was produced, which is associated with less active isomer byproducts (α -BHC, β -BHC, and δ -BHC), which are commonly removed before shipping (Geraghty and Miller, 1980). Pesticide byproducts were spread in unlined "basins" near the facility; this practice began in about 1958 and continued until 1975 when a treatment facility and double-lined ponds were constructed (Geraghty and Miller, 1980). Benzene, which was contaminated with organophosphate residues, was spilled upgradient from the evaporation ponds in 1979. The benzene may be enhancing the dissolution and migration of organochlorine pesticides into the ground-water environment. A contaminant plume containing these chemicals extends north of the facility (Geraghty and Miller, 1980). Agricultural chemical production ceased at the complex in about 1980.

An area 8 mi north of Fallon near the landfill site was established for disposal of agricultural pesticide containers. A trench was dug prior to 1972, when the University of Nevada-Reno, College of Agriculture, Cooperative Extension Service, began a study of

potential site contamination. Ethyl parathion, γ -BHC, and methyl parathion were detected in plants and soil near the site. The site was closed in 1985. In 1987, NDEP investigated and the trench was still exposed at that time. Water samples from a well drilled downgradient from the site revealed no ground-water contamination (Sertic and others, 1988).

Occasionally, sewage-treatment plants receive pesticides illegally dumped in the sanitary sewage system. Because the plants are not designed to remove these contaminants, some pesticides have been found in sewage outflow. In the Carson River Basin, no sewage-treatment plants (since 1987) discharge to surface water, but several do discharge to holding ponds and fields. In the Truckee River Basin, the Truckee Meadows Water Reclamation Facility discharges to Steamboat Creek, a tributary to the Truckee River; all others use land application for disposal. In Las Vegas Valley, sewage-treatment plants discharge to Las Vegas Wash and some land application is done also.

Landfills also may receive pesticides that have been disposed of improperly. Landfills are not designed to process such compounds and some pesticides may be found in leachate.

Temporal Trends in Pesticide Use

Pesticide use may change dramatically with time. Records of commercial applications for the past 10 years published by the Nevada Division of Agriculture (1982-91) show that many of the pesticides reported are used intermittently, with no use at all in some years (table 13). Few pesticides that were applied regularly during this period exhibited linearly increasing or decreasing usage. This may reflect fluctuations in insect infestations caused by biological cycles, climatic effects, or possibly market forces affecting purchases. Although few commercial applicators report use of pesticides after they have been banned, several did report use of pesticides as many as 10 years after they had been discontinued by the manufacturer.

DISTRIBUTION OF PESTICIDE ANALYSES AND DETECTIONS

Data on pesticide concentrations in natural waters were available for 291 sites in the study area (pls. 1 and 2 and apps. A and B). Differences in sampling and analyzing protocols make the data comparable only in a qualitative manner. The *p,p'*-DDT homologues and

Group A insecticides were sampled for most often, and no samples were analyzed for fungicides or rodenticides. The distribution of data may be considered in terms of sampled matrix, geographic location, or hydrologic setting. The distinction between resource type is not made in this analysis because virtually all surface-water sites are in perennial streams (a few are in Lake Mead) and virtually all ground-water sites are in basin-fill deposits.

Of the 190 pesticides with use reported in Nevada, 68 have been analyzed for and 34 have been detected. Of 23 herbicides analyzed for, 7 have been detected (30 percent). Only one fungicide (HCB) was sampled for and was detected. Of 38 insecticides analyzed for, 22 have been detected (58 percent). Of six degradation products analyzed for, four have been detected (67 percent). These figures highlight the need to include in analyses more of the approximately 190 pesticides that are known to have been used in the study area.

Distribution by Sample Matrix

Most analyses of surface and ground water were made on unfiltered samples. These analyses were used to describe the distribution of pesticides in water resources of the study unit (table 14). Pesticides were detected in surface water from 24 of 83 sites (29 percent). Las Vegas Valley had a significantly greater frequency of pesticide detection, from 21 of 33 surface-water sites (64 percent), than the other areas, and this may be related to a pesticide manufacturing site located in the lower part of the valley. The pesticides 2,4-D; 2,4,5-T; 2,4,5-TP; aldrin; α -BHC; β -BHC; diazinon; dicamba; dieldrin; *p,p'*-DDD; *p,p'*-DDE; *p,p'*-DDT; endrin; ethion; heptachlor epoxide; lindane; prometon; and simazine were detected.

Few studies of pesticide residues in fish in Nevada have been done. Fish bioaccumulate many pesticides and can be sensitive indicators of pesticides in aquatic ecosystems; however, some of the fish studies used insensitive detection limits that mitigate the advantage of using bioaccumulator species. Of the 18 sites where fish tissues were analyzed, 5 sites had pesticides detected (28 percent, table 14). The pesticides α -BHC, γ -BHC, chlordane, dacthal, dieldrin, *p,p'*-DDD, *p,p'*-DDE, *p,p'*-DDT, endrin, heptachlor, nonachlor, and toxaphene were detected. In the Las Vegas Valley area, pesticides were detected in two of three fish-tissue samples (67 percent).

All the pesticide detections in bottom sediments and fish tissue were significantly below the lethal dose estimates for rats and most detections in water were several orders of magnitude below the MCL's, except chlordane, endrin, heptachlor, heptachlor epoxide, lindane, and toxaphene, which exceeded the MCL's. All these pesticides also exceeded the water-quality criteria for protection of freshwater aquatic organisms;

aldrin, *p,p'*-DDD, *p,p'*-DDT, diazinon, dieldrin, endosulfan, and malathion also exceeded the water-quality criteria. All these pesticides are toxicity Class I or II except malathion and *p,p'*-DDD, which are Class III. The Class I and II pesticides tend to be analyzed for most often, and the higher rates of detection may be a function of sampling bias or may reflect higher levels of these pesticides in the environment.

Table 14. Distribution of pesticide detections by matrix, area, and hydrologic setting in Nevada Basin and Range NAWQA study unit, water years 1966-92

[---, no data available; NA, not applicable; ND, not determined]

Area or hydrologic setting	Ground water		Surface water		Fish tissue		Bottom material	
	Sites detected/ sites sampled	Sites detected, as percent of sites sampled	Sites detected/ sites sampled	Sites detected, as percent of sites sampled	Sites detected/ sites sampled	Sites detected, as percent of sites sampled	Sites detected/ sites sampled	Sites detected, as percent of sites sampled
Study unit totals	28/156	18	24/83	29	5/18	28	46/68	68
Las Vegas Valley area	15/35	43	21/33	64	2/3	67	2/3	67
Spring Mountains	0/4	0	--	--	ND	ND	ND	ND
Las Vegas Valley	15/31	48	14/21	67	ND	ND	ND	ND
Lake Mead	NA	NA	7/12	58	ND	ND	ND	ND
Carson River Basin	12/67	18	1/15	7	1/6	17	24/31	77
Sierra Nevada	--	--	0/1	0	ND	ND	ND	ND
Carson Valley	3/19	16	0/3	0	ND	ND	ND	ND
Eagle Valley	5/25	20	0/2	0	ND	ND	ND	ND
Dayton Valley	1/3	33	0/3	0	ND	ND	ND	ND
Churchill Valley	0/2	0	1/2	50	ND	ND	ND	ND
Carson Desert	3/18	17	0/4	0	ND	ND	ND	ND
Truckee River Basin	1/54	2	2/35	6	2/9	22	20/34	59
Truckee Canyon Segment	--	--	1/4	25	ND	ND	ND	ND
Lake Tahoe Basin	0/41	0	0/21	0	ND	ND	ND	ND
Washoe Valley	--	--	0/1	0	ND	ND	ND	ND
Truckee Meadows	0/6	0	0/5	0	ND	ND	ND	ND
Tracy Segment	--	--	0/2	0	ND	ND	ND	ND
Pyramid Lake	NA	NA	1/2	50	ND	ND	ND	ND
Fernley Area ¹	1/7	14	--	--	ND	ND	ND	ND
Headwater areas	8/95	8	1/37	3	ND	ND	ND	ND
Las Vegas Valley area	0/4	0	--	--	ND	ND	ND	ND
Carson River Basin	8/44	18	0/6	0	ND	ND	ND	ND
Truckee River Basin	0/47	0	1/31	3	ND	ND	ND	ND
Basin areas	20/61	33	23/46	50	ND	ND	ND	ND
Las Vegas Valley area	15/31	48	21/33	64	ND	ND	ND	ND
Carson River Basin	4/23	17	1/9	11	ND	ND	ND	ND
Truckee River Basin	1/7	14	1/4	25	ND	ND	ND	ND

¹ Fernley Area included because Truckee Canal flows through it.

Bottom sediments were sampled 68 times, mostly in the Carson and Truckee Rivers. Bottom sediments may accumulate hydrophobic compounds concentrating them enough to be detected. Of the 68 sites where bottom sediments were sampled, pesticides were detected at 46 sites (68 percent, table 14). The pesticides 2,4,5-TP, aldrin, chlordane, dieldrin, *p,p'*-DDD, *p,p'*-DDE, *p,p'*-DDT, endosulfan, endrin, heptachlor, heptachlor epoxide, lindane, methoxychlor, and toxaphene were detected.

Areal Distribution

Pesticide detections from surface-water and ground-water sampling sites were distributed in the study unit as follows: 36 of 68 sites (53 percent) in the Las Vegas Valley area; 13 of 82 sites (16 percent) in Carson River Basin; and 3 of 89 sites (3 percent) in Truckee River Basin (table 14).

Las Vegas Valley Area

Pesticide data for surface water were available for 33 sites in the Las Vegas Valley area (pl. 1, table 14, and app. A). Twenty-one of the sites (64 percent) had detectable concentrations of at least one pesticide. Of the 21 sites in the lower Las Vegas Valley, including Las Vegas Wash and its tributaries, pesticides were detected at 14 (67 percent). Of the 12 sites in Lake Mead, pesticides were detected at 7 (58 percent). The detected pesticides were herbicides 2,4-D, 2,4,5-T, 2,4,5-TP; and insecticides aldrin, chlordane, *p,p'*-DDD, *p,p'*-DDE, *p,p'*-DDT, dacthal, dieldrin, endrin, heptachlor, lindane, nonachlor, and toxaphene. All pesticides had recent and historical use. All sites tested positive for some *p,p'*-DDT homologues.

Most of the 35 ground-water sites in the Las Vegas Valley area (pl. 1, table 14, and app. B) are in the Las Vegas urban area. Four sites are located in the Spring Mountains. Pesticide residues were found in samples at 15 sites (43 percent). Samples from 12 wells and 1 ground-water drain near Henderson tested positive for insecticides aldrin, diazinon, and lindane. No pesticide residues were detected in samples from four springs in the Spring Mountains.

Carson River Basin

Data on pesticides in surface water are available for 15 sites in the Carson River Basin with one to four sites in each valley (pl. 2, table 14, and app. A). Only 1 of the 15 sites had a pesticide detection (7 percent). Ground-water samples in the Carson River Basin were collected at 67 sites (pl. 2, table 14, and app. B), 56 of these sites were sampled during the pilot NAWQA study. Samples from 12 sites had detectable amounts of pesticides (18 percent). Five of the wells were in the Carson City urban area and one was in Gardnerville. The pesticides detected in urban wells were the herbicides dicamba and prometon and the insecticides *p,p'*-DDT and heptachlor epoxide (a degradation product of heptachlor). Heptachlor and *p,p'*-DDT had no urban use reported in the past decade. Five wells sampled were in agricultural areas. The wells tested positive for the herbicides 2,4-D; 2,4,5-TP; dicamba; or simazine, and the insecticides *p,p'*-DDD, *p,p'*-DDT, dieldrin, endrin, ethion, heptachlor, heptachlor epoxide, or lindane. This distribution pattern indicates that pesticides not recently used (*p,p'*-DDT, dieldrin, endrin, and heptachlor) are persistent and still being detected in ground water.

Truckee River Basin

Most of the surface-water sites sampled for pesticides in the Truckee River Basin are in the Lake Tahoe Basin; no pesticides were detected (pl. 2, table 14, and app. A). Only 2 of the 35 surface-water sites had pesticide detections (6 percent). Ground-water samples in the Truckee River Basin (54 sites) were collected by State agencies that regulate public drinking-water supplies (pl. 2, table 14, and app. B). The sites were mainly in population centers and include 41 sites in the Lake Tahoe Basin, 6 in Truckee Meadows, and 7 in the Fernley area. Only a few sites were sampled prior to 1984. Water from 1 of the 54 wells (2 percent) contained a pesticide residue (heptachlor epoxide).

Distribution by Hydrologic Setting

Surface- and ground-water samples were collected at 132 sites in the headwater areas (table 14); pesticides were detected at 9 sites (7 percent). Pesticide residues were detected in surface-water samples from 1 of 37 sites (3 percent), and in ground-water samples from 8 of 95 sites (8 percent).

Of the 107 surface- and ground-water sites sampled in the downstream basin areas (table 14), pesticides were detected at 43 (40 percent). Pesticide residues were detected in surface-water samples at 23 of 46 sites (50 percent) and in ground-water samples from 20 of 61 sites (33 percent).

TEMPORAL VARIATIONS IN PESTICIDE CONCENTRATIONS

Long-term time-dependant records of pesticide residues are available for a few surface-water sites within the study area. None of the data are detailed enough to determine trends, but the data are considered to be of high quality and can be used quantitatively. Data are available for 1974-80 for pesticide residues in water samples from two surface-water sites: Las Vegas Wash near Boulder City (site 18, pl. 1 and app. A) and Truckee River at Lockwood (site 158, pl. 2 and app. A). The data were collected by the USGS as part of a nationwide study. No long-term data are available for the Carson River. The data are plotted in figures 58-61; the vertical scales are logarithmic and a value of zero is not on such a scale. Values plotted below the laboratory reporting limit indicate that an analysis was made but the pesticide compound was not detected. Data also are available for 1970-84 for organochlorine insecticide residues in fish from two sites: Lake Mead (site 21, pl. 1 and app. A) and Truckee River near Fernley (site 168, pl. 2 and app. A). The data were collected by the USFWS as part of a nationwide study (Schmitt and others, 1985).

Data collected by USGS for pesticides in water samples from Las Vegas Wash near Boulder City (fig. 58), downstream of the metropolitan Las Vegas area, sewage-treatment plants, and a complex near Henderson where pesticides were manufactured, include water years 1974-80. The pesticides chlordane, endosulfan, ethion, heptachlor, heptachlor epoxide, malathion, methoxychlor, methyl parathion, methyl trithion, parathion, perthane, toxaphene, and trithion were analyzed for but not detected. Data for the pesticides (*p,p'*-DDD, *p,p'*-DDE, and dieldrin) discontinued in the 1970's and 1980's are too few to determine a trend, and are near the laboratory reporting limit of 0.01 µg/L (fig. 58). Data for pesticides still in use suggest that 2,4-D and diazinon may have been increasing and that lindane may have been decreasing during 1974-80. The higher solubilities of 2,4-D and diazinon (890 and 40 mg/L, respectively) relative to aldrin,

p,p'-DDD, *p,p'*-DDE, dieldrin, lindane, and 2,4,5-T (all are less than or equal to 10 mg/L) may partly explain these findings.

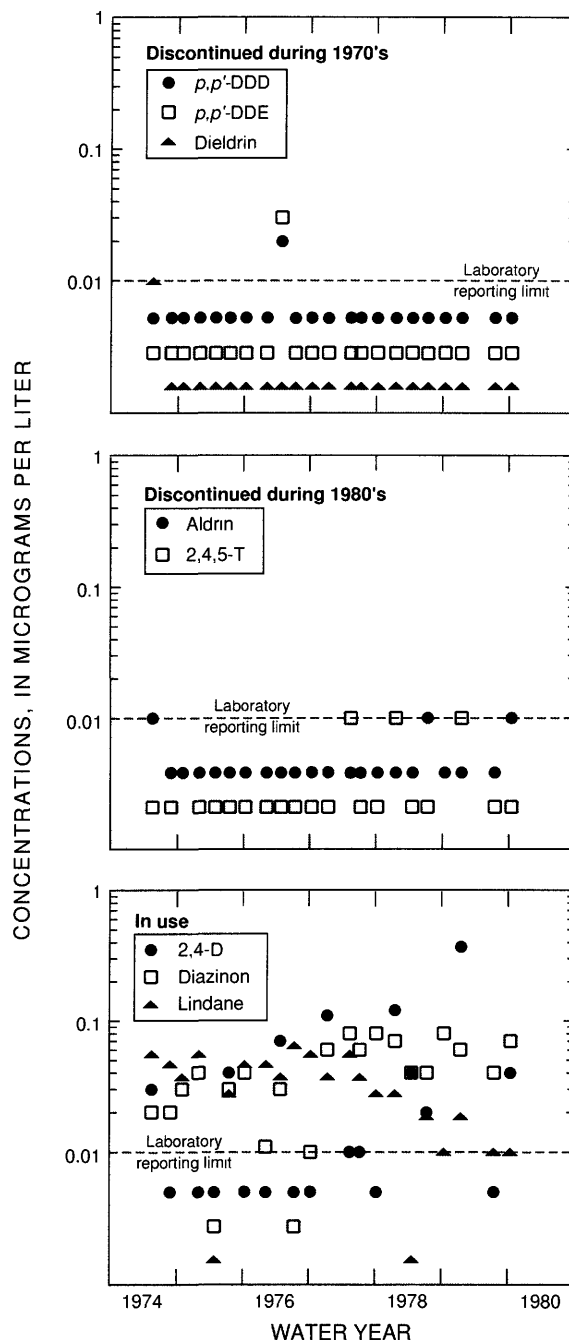


Figure 58. Pesticide concentrations detected in water samples from Las Vegas Wash near Boulder City (site 18, pl. 1 and app. A), water years 1974-80. Samples with concentrations less than reporting limit are plotted in shaded area at bottom of each graph.

Pesticide data for water samples collected by the USGS for the Truckee River at Lockwood (site 158, pl. 2 and app. A) are shown in figure 59. The pesticides aldrin, chlordane, *p,p'*-DDD, *p,p'*-DDE, *p,p'*-DDT, dieldrin, endrin, ethion, heptachlor, heptachlor epoxide (a degradation product of heptachlor), lindane, methyl parathion, methyl trithion, methoxychlor, mirex, parathion, perthane, and toxaphene were analyzed for, but not detected. Diazinon; endosulfan; 2,4-D; and 2,4,5-T were detected. Temporal variations of pesticide concentrations for water samples from the Truckee River at Lockwood are ambiguous.

The USFWS study of pesticide residues in fish tissue was hampered by changes in analyzing laboratories in 1972 and 1975 and changes in chromatograph technique in 1975 (Schmitt and others, 1985). The USFWS site in Lake Mead (site 21, pl. 1 and app. A) is downstream from Las Vegas, the sewage-treatment plants, and the complex near Henderson. The pesticides *p,p'*-DDD, *p,p'*-DDE, *p,p'*-DDT, dieldrin, endrin, heptachlor, toxaphene, and α -BHC were detected during the early 1970's and the 1980's (fig. 60). The pesticides dacthal, HCB, methoxychlor, mirex, and oxychlordane were analyzed for, but not detected. Chlordane and nonachlor were detected a few times, but are not plotted on figure 60. Temporal variations of pesticide concentrations show no consistent trend or pattern for fish-tissue samples from Lake Mead.

For the USFWS site on the Truckee River near Fernley (site 168, pl. 2 and app. A), the pesticides dacthal, HCB, methoxychlor, mirex, and oxychlordane were analyzed for but not detected. Chlordane was detected during the 3 years it was analyzed for, but is not shown on figure 61. The limited data for pesticides discontinued in the early 1970's (*p,p'*-DDD, *p,p'*-DDE, *p,p'*-DDT, and dieldrin) suggest that concentrations

may have declined from 1970 to 1984. Temporal variations for pesticides discontinued in the late 1980's and those still in use are not clear.

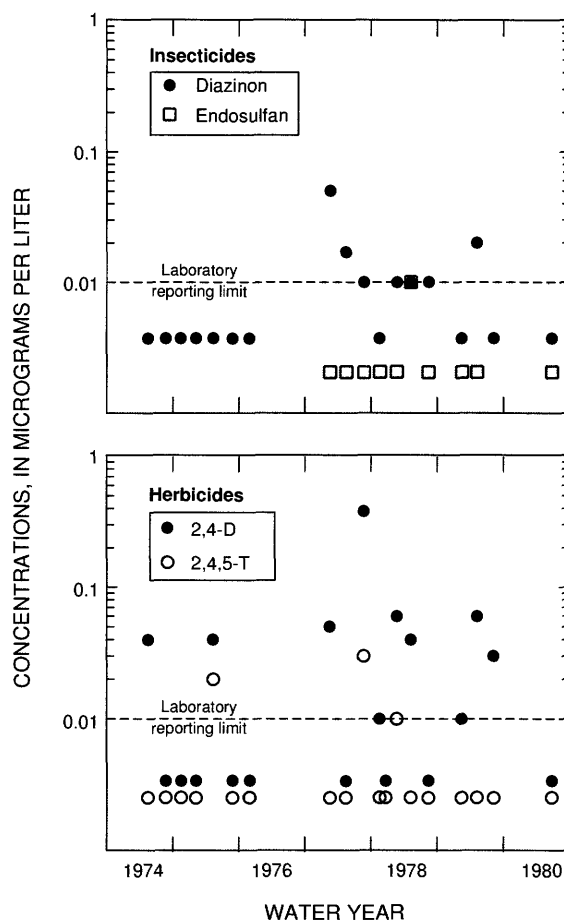


Figure 59. Pesticide concentrations detected in water samples from Truckee River at Lockwood (site 158, pl. 2 and app. A), water years 1974-80. Samples with concentrations less than reporting limits are plotted in shaded area at bottom of each graph.

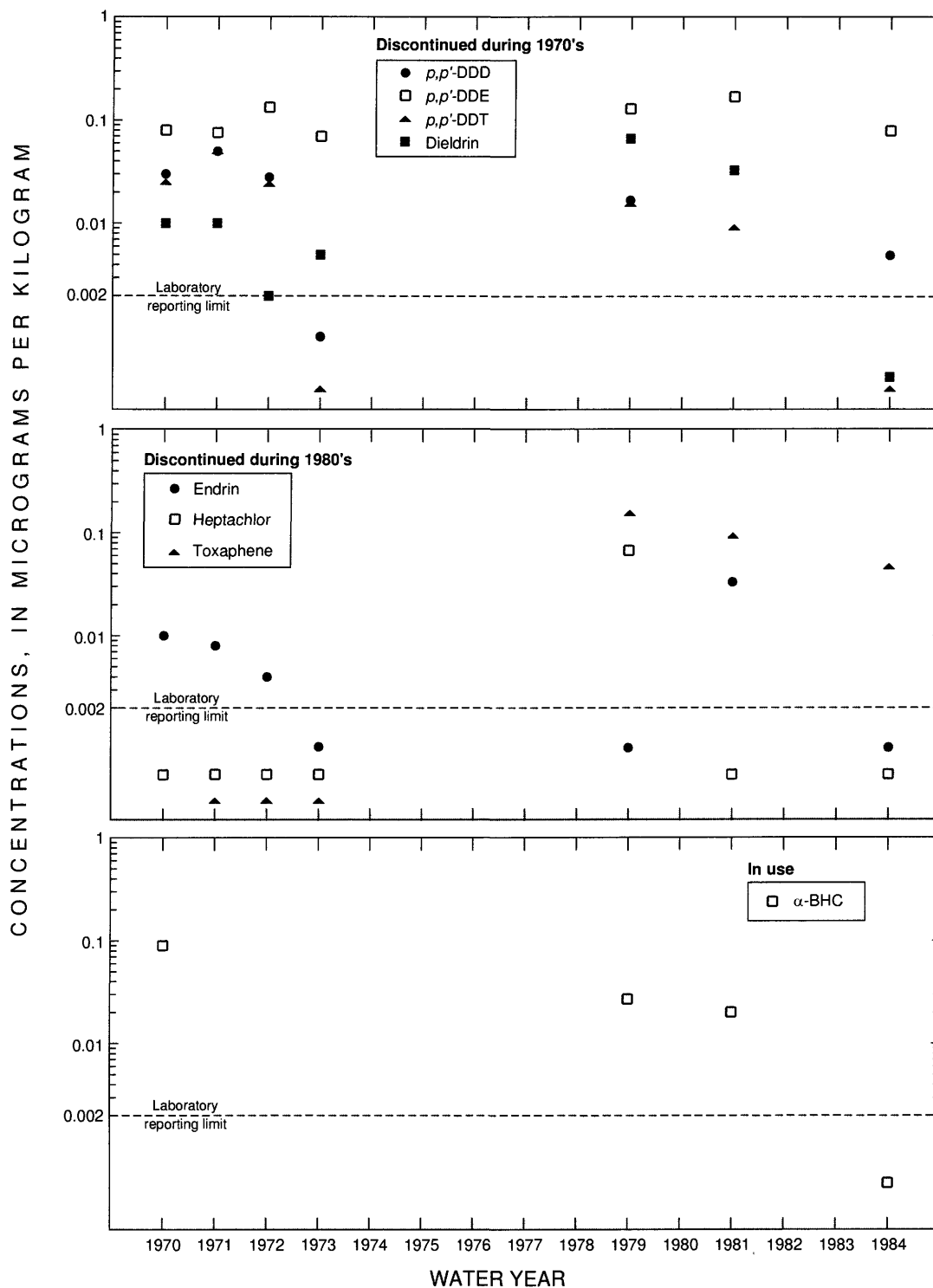


Figure 60. Pesticide concentrations detected in whole adult fish samples from Lake Mead near Las Vegas (site 21, pl. 1 and app. A), water years 1970-84. Samples with concentrations less than reporting limit are plotted in shaded area at bottom of each graph.

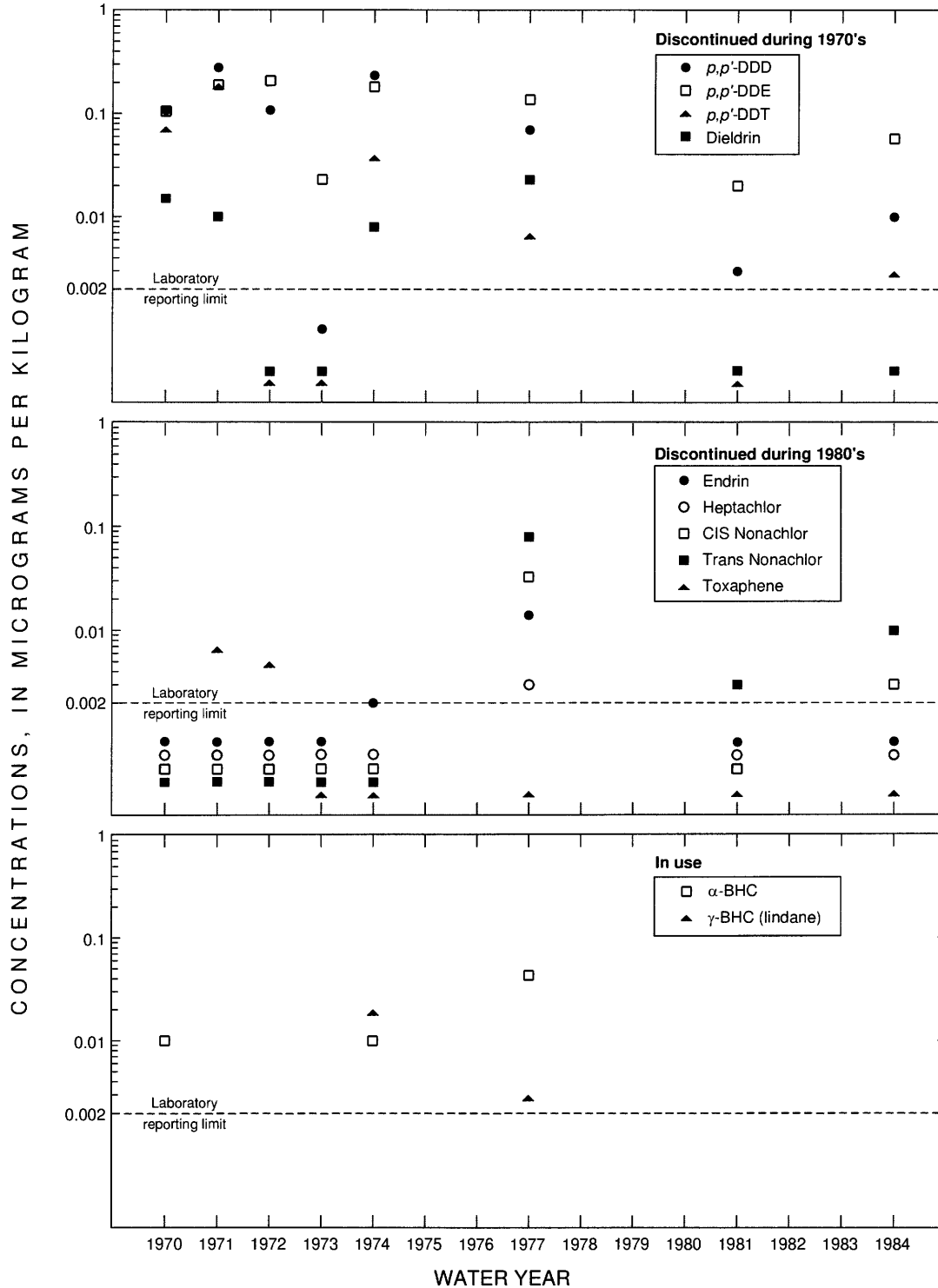


Figure 61. Pesticide concentrations detected in whole adult fish samples from Truckee River near Fernley, Nev. (site 168, pl. 2 and app. A), water years 1970-84. Samples with concentrations less than reporting limits are plotted in shaded area at bottom of each graph.

SUSPENDED SEDIMENT IN SURFACE WATER

by Hugh E. Bevens

INTRODUCTION

The transport of suspended sediment by streams and rivers is a water-quality concern that is related to soil and water resources. The rate of sediment transport at a stream site is directly related to the rate of soil erosion by water in the upstream watershed and to the rate of sediment deposition by water in downstream areas. Erosion of land surfaces results in the loss of valuable topsoil; erosion of stream channels impairs riparian and aquatic habitat. Sediment deposition in stream channels and impoundments impairs aquatic habitat and increases the potential for flooding owing to decreased storage capacities. In the NVBR study unit (pls. 1 and 2), sediment-transport rates are affected by environmental factors and human activities.

Runoff is the most important environmental factor affecting sediment-transport rates. Without runoff, either as overland flow or as ground-water discharge to streams, erosion by water is not possible. In the NVBR study unit, nearly all precipitation falls as snow in headwater areas and most of the runoff to streams is by snowmelt in headwater areas. However, infrequent episodes of rainfall runoff in headwater or basin areas can cause large increases in sediment-transport rates. Other important environmental factors include surface slope and vegetative cover. Avalanches, landslides, forest fires, and debris flows can contribute large loads of sediment to streams by direct transport or by destroying vegetation and disturbing soil, which accelerate erosion.

Human activities in the NVBR study unit that have the potential for affecting sediment-transport rates include urbanization, agriculture, and mining. Clearing land for urban development exposes and disturbs soils. Impervious urban areas can increase overland runoff, increasing erosion of adjacent land surfaces and stream channels. Point-source discharges of treated sewage or other effluent and drainage of shallow ground water from landscape irrigation and septic fields can increase streamflow, causing stream-channel erosion.

Cultivation of land for agricultural purposes in the NVBR study unit is limited; the principal crops, alfalfa and pasture, require little cultivation. Livestock grazing, on range and irrigated pasture, is a widespread agricultural activity with the potential for affecting sediment transport. Grazing can reduce vegetative cover on pasture, range, and riparian areas and can disturb soils. Lumbering activities (timber harvesting and road building) are limited, in the study unit, but do remove vegetative cover and disturb soils.

Mining has the potential for increasing rates of sediment transport. Historic hard-rock mining and milling for silver and gold in localized areas of the NVBR study unit have left mine tailings and mill spoils exposed to erosional processes. Modern open-pit mining operations disturb large areas of the land surface and expose much larger areas of soils to erosion. Dewatering of deep open-pit mines can increase erosion if the water is discharged into surface drainages.

Purpose and Scope of This Section

This section of the report provides a retrospective analysis of available suspended-sediment information and data for the Las Vegas Valley area and the Carson and Truckee River Basins. Important findings of previous investigations are reviewed. Available suspended-sediment records of streamflow sites for October 1979 through April 1990 are evaluated with respect to temporal and hydrologic representativeness. This period of record, which is water year 1980 through April 1990, was selected as representative of current conditions as of 1993. Those sites that adequately represent the period of record are used to describe areal and temporal variations of suspended-sediment concentrations. Seasonal and annual suspended-sediment loads are determined for those sites with significant statistical relations between streamflow and loads. Variations in concentrations and loads of suspended sediment are discussed in relation to environmental factors and human activities.

Previous Investigations

Suspended-sediment transport in Las Vegas Valley has been investigated to determine the effects and magnitude of erosion in Las Vegas Wash that have resulted from rapid urbanization of the Las Vegas metropolitan area. Las Vegas Wash, a historically ephemeral stream, became perennial in 1955 as a result of wastewater discharge from the Las Vegas area

(Glancy and Whitney, 1989). Erosion of Las Vegas Wash, primarily by vertical and lateral channel enlargement, has rapidly progressed since 1980 owing to wastewater discharge and superimposed flood flows that have increased because of intensive urbanization. During 1969-84, approximately 112 million cubic feet of sediment (enough sediment to cover 1 mi² to a depth of 4 ft) were eroded from Las Vegas Wash and deposited in Las Vegas Bay of Lake Mead (Glancy and Whitney, 1986).

Sediment transport in the Carson River Basin has been the subject of investigations by Katzer and Bennett (1983) and by Garcia and Carman (1986). A sediment-transport model developed for the reach of the East Fork Carson River that flows through Carson Valley (Katzer and Bennett, 1983) estimated that the average annual sediment load (bed load and suspended sediment) transported into the reach was about 50,000 tons and the average annual load transported out of the reach was about 24,000 tons. The reach was aggrading because of sediment deposition. The ratio of suspended sediment to bedload in loads measured during that study ranged from 0.5 to 294. Garcia and Carman (1986) estimated that the Carson River contributed about 230,000 tons of suspended sediment to Lahontan Reservoir during the 1980 water year, and that the trapping efficiency of the reservoir was about 91 percent.

USGS has operated a National Stream-Quality Accounting Network (NASQAN) site at the Carson River near Fort Churchill since 1975. NASQAN is a nationwide stream water-quality network with sites located at or near the downstream ends of major hydrographic basins. The network provides consistent, long-term data on the quality (including suspended sediment) and streamflow of major surface-water systems in the United States. The USGS has operated a NASQAN site at the Truckee River near Nixon, Nev., since 1973.

Most of the investigations concerning the transport of suspended sediment in the NVBR study unit have been in the Lake Tahoe Basin, in the headwater area of the Truckee River Basin. These studies resulted from concerns about the observed acceleration of eutrophication in Lake Tahoe, indicated by measured annual increases in primary productivity of about 6 percent during 1967-86 and corresponding decreases in clarity of about 1.3 ft/yr (Goldman, 1990). The increase in primary productivity corresponds to an increase in human population in the Lake Tahoe Basin; increased watershed loading of nutrients caused by human activities has been identified as a causal factor. Eutrophica-

tion is controlled primarily by the availability of nutrients; suspended sediment is a major source of nutrients and turbidity.

During the early 1970's, studies of Glenbrook Creek (Glancy, 1977) and the Incline Village area (Glancy, 1988) in Nevada indicated that developed areas yielded about 10 times more sediment than undeveloped areas; roadways were determined to be the principal source. A study of sediment transport from highway cut-slopes in the California side of the Lake Tahoe Basin (Kroll, 1976), estimated that about 2 percent of the fine sediment (silt and clay) transported to Lake Tahoe was from cut-slopes along California highways. Results of these three studies indicated that more than 60 percent of the sediment loads were transported by snowmelt runoff. In a study of 25 small watersheds in the Lake Tahoe Basin and headwater areas of the Truckee River Basin (Brown and others, 1973), multiple regression indicated that mean land-surface slope and percent of the area in urban development were principal factors affecting suspended-sediment transport.

In October 1979, a stream-monitoring network for nutrients and suspended sediment was established as part of the comprehensive Interagency Tahoe Monitoring Program, which also includes lake and atmospheric-deposition networks. USGS operates suspended-sediment sites on selected tributary streams as part of this program. In October 1987, the Nevada District Office of the USGS joined the program and began operating nutrient and suspended-sediment sites on additional tributary streams.

Hill and Nolan (1990) used multiple-regression analysis to evaluate factors that affect variations in average annual suspended-sediment yields of Lake Tahoe tributary streams. Analyses of 22 independent variables and concurrent sediment records for nine streams showed that density of the drainage system was the most important factor affecting variability in suspended-sediment yields, but that total road miles was also a useful factor in accounting for the variability. Further work by Nolan and Hill (1991) showed that stream-channel erosion mobilized more than 95 percent of the sediment transported by three Lake Tahoe tributary streams. This suggests that land-use changes that increase runoff or sediment supply could cause channel changes that might increase sediment discharge. These land-use changes could be anywhere in a drainage basin.

The USGS has operated a Hydrologic Benchmark Network station on Sagehen Creek near Truckee since the mid 1980's. This nationwide network has sites located in a small undeveloped drainage basins to provide long-term consistent hydrologic data that can be used to describe background conditions and to compare with conditions observed in basins affected by human activities.

Glancy and others (1972) evaluated runoff, erosion, and solutes in the lower Truckee River during 1969. During that year, while streamflow was nearly four times the long-term average, the sediment load for the Truckee River near Nixon was estimated to be 630,000 tons, of which about 10 percent was bedload. Riverbank erosion below the site contributed an estimated 6.8 million tons. A short period of local rainfall produced the highest concentrations of suspended sediment measured during 1969, but most of the suspended-sediment yield resulted from snowmelt runoff.

Concentrations of suspended sediment in the Carson and Truckee River Basins were discussed in the USGS National Water Summary 1990-91 (Seiler, 1993; Smith and others, 1993). Suspended-sediment data for water years 1980-89 were used to evaluate trends and develop statistical summaries representing National land-use categories. No trends were determined in suspended-sediment concentrations for the Carson River near Fort Churchill and the Truckee River near Nixon according to Seiler (1993). Smith and others (1993) developed statistical summaries of suspended-sediment concentrations for selected large-scale land uses, by using data sampled from a National geographically representative subset of stream water-quality stations. Selected land-use categories and median suspended-sediment concentrations were forest, 19 mg/L; urban, 25 mg/L; agriculture, 131 mg/L; and range, 230 mg/L. They also determined an average 10-year median flow-adjusted suspended-sediment yield for sites in the Great Basin of about 21 ton/mi²; a 0.2-percent-per-year decrease in suspended-sediment yield was measured. Nationally, annual suspended-sediment yields, in tons per square mile, were estimated to be about 31 for forest, 23 for urban, 10 for agriculture (wheat), and 33 for range areas.

Evaluation and Selection of Suspended-Sediment Records

Suspended-sediment records that were evaluated and interpreted for this analysis are limited to those in the USGS National Water Information Service

(Maddy and others, 1989) and the U.S. Environmental Protection Agency STORET data bases. Records were retrieved from these data bases for October 1969 through April 1990. Only stream-sediment records were evaluated; data for parking-lot runoff, storm drains, ditches, roads, canals, lakes, and other non-stream sites were not used. In this section, records for long-term suspended-sediment sites were evaluated, and representative suspended-sediment data were selected for describing and determining causes of areal and temporal variations in suspended-sediment concentrations and loads.

Long-Term Suspended-Sediment Records

Long-term suspended-sediment sites in the NVBR study unit (pls. 1 and 2, and app. A) have been operated by USGS and the U.S. Forest Service (USFS). The records from these sites include suspended-sediment concentrations and corresponding streamflow values. Suspended-sediment records that did not have corresponding streamflow values and those that did not include data through at least 1985 were not included. Appendix A lists the site identification number, site name, drainage area, latitude and longitude, collecting agency, period of record, and number of samples collected. Map numbers in the table correspond to those shown on plates 1 and 2.

Most of the long-term suspended-sediment sites are in the Lake Tahoe drainage basin (29 of the 36 listed in app. A and shown on pls. 1 and 2). These sites are operated on Lake Tahoe tributary streams by USGS and USFS to provide information about the transport of nutrients and sediment to Lake Tahoe. Additional long-term sites in the NVBR study unit have been operated by the USGS, including Las Vegas Wash near Henderson (site 13) and near Boulder City (site 18), Carson River near Fort Churchill (site 46, a NASQAN site), Martis Creek at Highway 267 (site 128) and near Truckee (site 130), Sagehen Creek near Truckee (site 132, a Hydrologic Benchmark Network station), and Truckee River near Nixon (site 171, a NASQAN site).

Selected Suspended-Sediment Records

Before available long-term data can be used to describe the areas and temporal variation of suspended-sediment concentrations and loads, and to relate these variations to environmental characteristics, the records must be evaluated to ensure that they are of sufficient and consistent quality and are representative of the

period of record. Only suspended-sediment records for USGS sites were selected because they were the only sites with continuous streamflow records. Suspended-sediment collection methods (Guy and Norman, 1976) and analytical procedures (Guy, 1969) are consistent and documented for these sites. Streamflow records are needed to determine if the sediment data are hydrologically representative and to determine sediment transport.

The data were evaluated to select the most representative records available. The first step in the evaluation process was to select records that are representative of current conditions. For this process, current is defined as water year 1980 through April 1990. The number of sediment samples analyzed during each year of the current period was plotted for each site. Eleven sites (app. A and pls. 1 and 2)—Las Vegas Wash near Boulder City (site 18), Carson River near Fort Churchill (site 46), Upper Truckee River at South Lake Tahoe (site 77), General Creek near Meeks Bay (site 80), Blackwood Creek near Tahoe City (site 83), Ward Creek at Highway 89 (site 84), Third Creek near Crystal Bay (site 93), Trout Creek near Tahoe Valley (site 110), Martis Creek near Truckee (site 130), Sagehen Creek near Truckee (site 132), and Truckee River near Nixon (site 171)—have sediment analyses for more than one-half of the years included in the current period. Martis Creek near Truckee is affected by a reservoir and was dropped from further consideration. Data for the remaining 10 sites were then evaluated for seasonal representativeness (winter, January-March; spring, April-June; summer, July-September; and autumn, October-December). Each of the 10 sites has at least a few samples that were collected during each season.

The final step in the evaluation process was to examine the representativeness of suspended-sediment records with respect to long-term streamflow conditions (water year 1970-April 1990). The number of suspended-sediment samples was plotted for streamflow deciles ranging from 1 through 10 (10th through 100th percentile) for each of the 10 stations. Only seven sites—Las Vegas Wash near Boulder City (site 18), Carson River near Fort Churchill (site 46), Upper Truckee River at South Lake Tahoe (site 77), Third Creek near Crystal Bay (site 93), Trout Creek near Tahoe Valley (site 110), Sagehen Creek near Truckee (site 132), and Truckee River near Nixon (site 171)—had suspended-sediment records that were representative of streamflow. Much of the suspended-sediment data available for these sites was collected by a

periodic-sampling strategy, rather than a storm-runoff sampling strategy. Therefore, relatively short periods of intense sediment transport associated with storm runoff could be underrepresented. Las Vegas Wash near Boulder City did not have sediment samples collected during streamflow that was equal to or less than the 40th percentile of long-term streamflow. This distribution is a result of the increase in effluent from Las Vegas area sewage-treatment facilities, which has caused mean daily flow in Las Vegas Wash to increase from about 42 ft³/s in water year 1970 to about 170 ft³/s in water year 1990. The suspended-sediment data were collected during water years 1980 through 1985, when mean daily flow increased from about 81 to 120 ft³/s. Suspended-sediment data for Las Vegas Wash, although not representative of long-term (water year 1970-April 1990) streamflow at that site, were selected as being representative of current conditions because they were collected during streamflows that are reasonably representative of current (water year 1980-April 1990) flows. The evaluation process for suspended-sediment data collected during water year 1980-April 1990 is illustrated by graphs for the seven sites that were selected as being representative, showing the number of samples collected during each water year (fig. 62), the number of samples collected during each season (fig. 63), and the number of samples collected during each streamflow decile (fig. 64).

SUSPENDED-SEDIMENT CONCENTRATIONS

Many of the suspended-sediment samples from streams draining headwater areas were collected during the spring (see sites 77, 93, 110, and 132 on figs. 63 and 64); spring runoff generates high rates of streamflow that can transport large amounts of suspended sediment. Recent records (October 1979- April 1990) were seasonally normalized to obtain more representative suspended-sediment data for the selected sites. The normalization process utilized stratified random subsampling to develop more numerically balanced subsets of seasonal samples. Seasonal statistical summaries of the normalized data for the seven selected sites are shown as boxplots in figure 65 and listed in table 15.

The variability of suspended-sediment concentrations can be a result of many factors, most of which also affect streamflow variability. Factors that increase overland runoff generally cause higher streamflows and suspended-sediment concentrations. However,

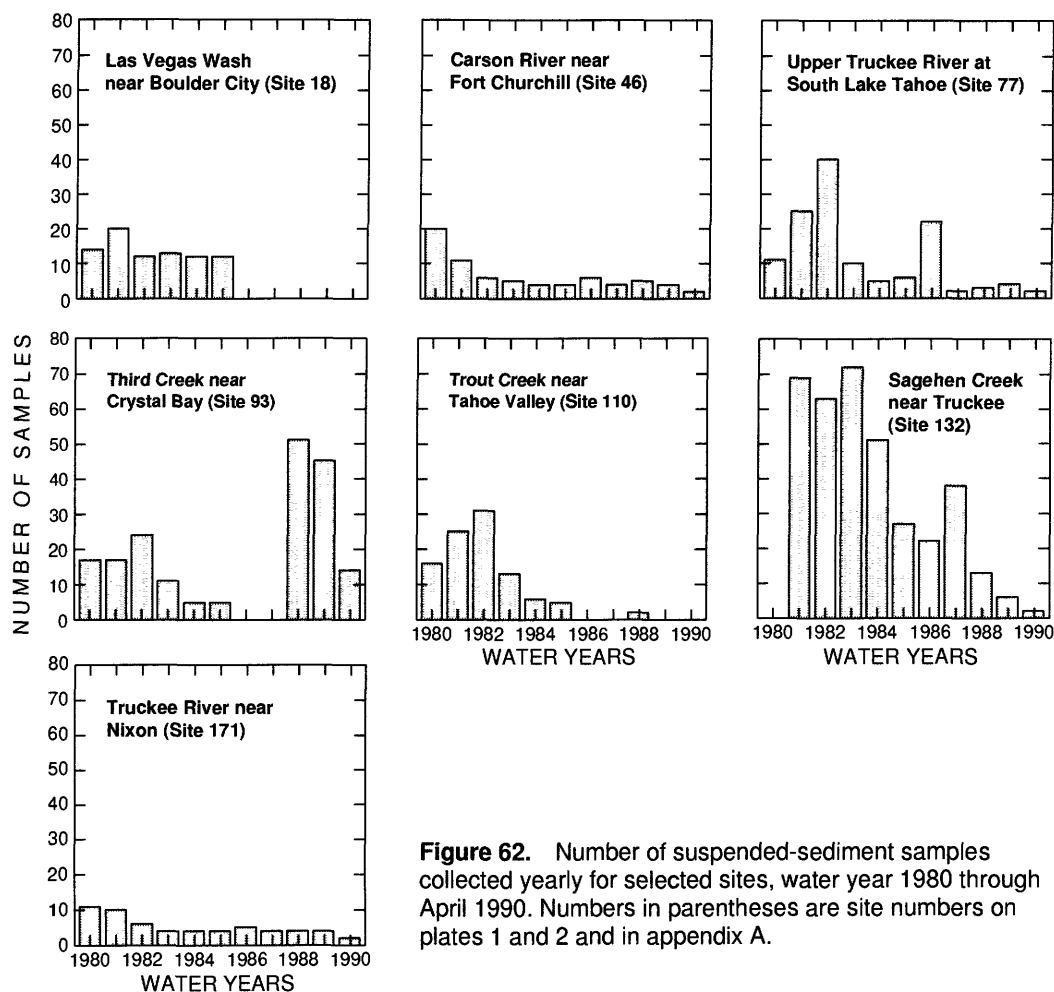


Figure 62. Number of suspended-sediment samples collected yearly for selected sites, water year 1980 through April 1990. Numbers in parentheses are site numbers on plates 1 and 2 and in appendix A.

The variability of suspended-sediment concentrations can be a result of many factors, most of which also affect streamflow variability. Factors that increase overland runoff generally cause higher streamflows and suspended-sediment concentrations. However, increased streamflow from point-source discharges can cause stream-channel erosion, which also results in increased suspended-sediment concentrations. Statistical summaries of the seasonally normalized suspended-sediment concentration data for discharge quartiles (fig. 66 and table 16) clearly show that suspended-sediment concentrations increased as streamflow increased. Factors that cause variability in streamflow rates and suspended sediment concentrations can be caused by areal and temporal differences.

Areal Variations

Areal variations in suspended-sediment concentrations can be caused by a number of physical factors. Although the number of sites with adequate data are sparse, some generalizations can be made about the areal variability of suspended-sediment concentrations by evaluating the statistically summarized data shown in figure 67 and table 17.

Streamflow at all the stations, except Las Vegas Wash near Boulder City (site 18, pl. 1), is primarily from snowmelt runoff in headwater areas of the Sierra Nevada. The Upper Truckee River at South Lake Tahoe (site 77), Third Creek near Crystal Bay (site 93), Trout Creek near Tahoe Valley (site 110), and Sagehen Creek near Truckee (site 132) are sites on unregulated headwater-area streams (pl. 2). The Carson River near Fort

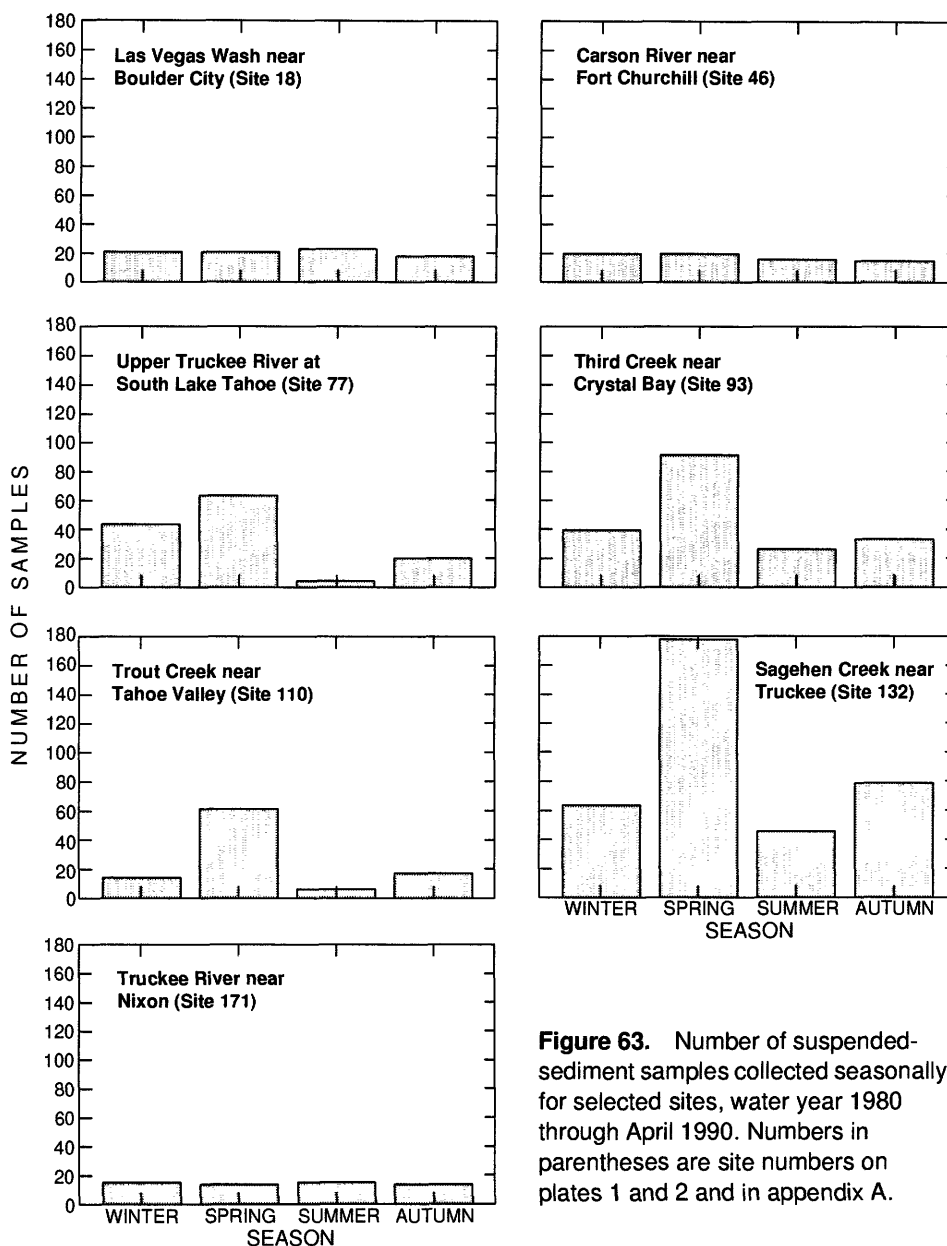


Figure 63. Number of suspended-sediment samples collected seasonally for selected sites, water year 1980 through April 1990. Numbers in parentheses are site numbers on plates 1 and 2 and in appendix A.

Churchill (site 46, pl. 2) is mostly unregulated, except for irrigation diversions and return flows. Streamflow in the Truckee River near Nixon (site 171, pl. 2) is controlled by Lake Tahoe and other regulated impoundments in the Sierra Nevada, including Stampede, Boca, Prosser, and Martis Creek Reservoirs and Independence and Donner Lakes (pl. 2). Discharge of treated sewage from the cities of Reno and Sparks (which averaged about 35 ft³/s during the current period) and irrigation diversions to the Truckee Canal (which averaged about 250 ft³/s during the current period) and other canals also affect this site. Flow in Las Vegas

Wash near Boulder City, which is primarily from treated sewage effluent (nearly 86 percent in water year 1990), became perennial in 1955 and has increased from about 42 ft³/s in water year 1970 to about 81 ft³/s in water year 1980, and to about 170 ft³/s in water year 1990.

The low concentrations of suspended sediment in samples from Sagehen Creek near Truckee, relative to the other unregulated headwater-area streams, could be due to the absence of urban and agricultural land use in its watershed (fig. 67 and table 18). The low concentrations in samples from the Truckee River near Nixon

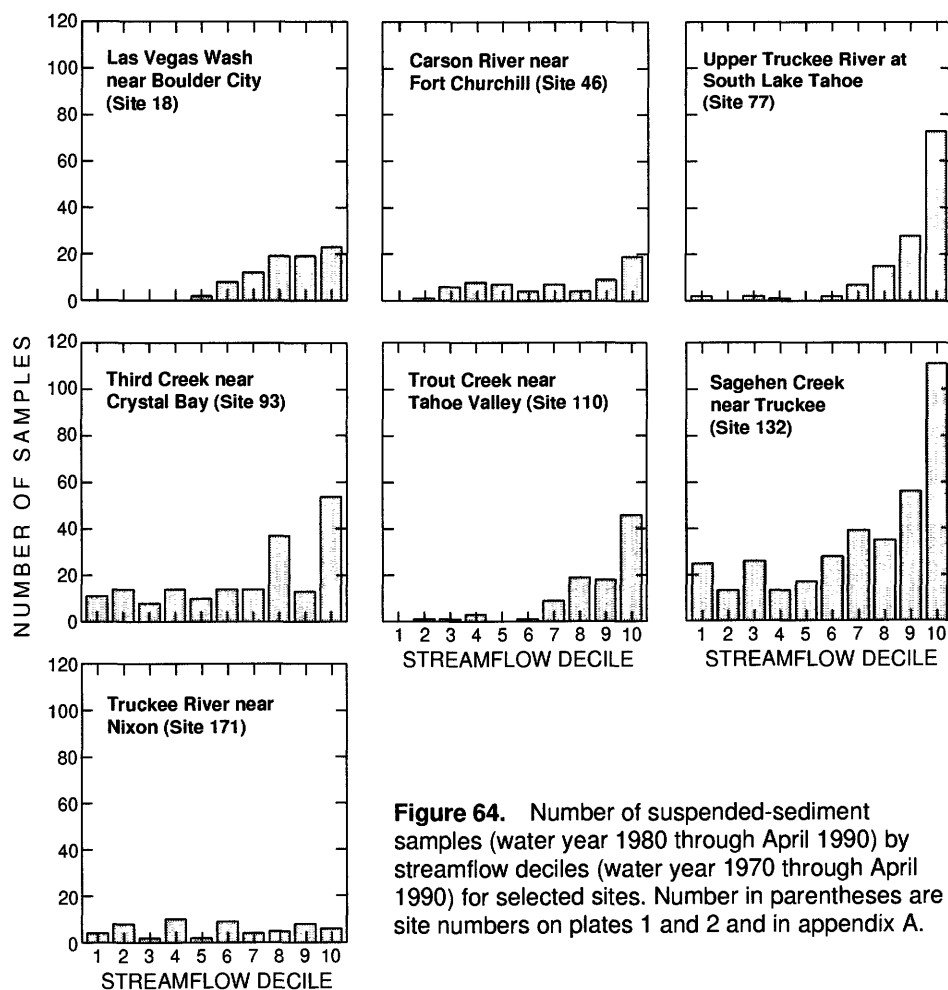


Figure 64. Number of suspended-sediment samples (water year 1980 through April 1990) by streamflow deciles (water year 1970 through April 1990) for selected sites. Number in parentheses are site numbers on plates 1 and 2 and in appendix A.

could be a result of a large part of the flow being provided by lake outflows and reservoir releases; the watershed of this site has the largest amount (11.6 percent) of open water. The Carson River near Fort Churchill has the highest percentage of agricultural land (6.7 percent in table 18) and the second highest 75th and 90th percentile concentrations of suspended sediment (table 17). The high concentrations of suspended sediment in samples from the Las Vegas Wash near Boulder City are because of channel erosion caused by increasing rates of treated sewage effluent and by enhanced flood volumes and peaks caused by urbanization (Glancy and Whitney, 1986). Although table 18 shows that urbanization only accounts for about 5 percent of the watershed, most of the flow at the site comes from the urban area. Third Creek near Crystal Bay has the most urbanized watershed (9.9 percent) and the third highest 75th and 90th percentile suspended sediment concentrations (table 17).

Land use has been shown to be an important factor affecting instream suspended-sediment concentrations. Smith and others (1993) used national suspended-sediment data to develop statistical summaries for selected land uses. Statistical summaries of suspended-sediment concentration data for these national land-use designations are in table 19. Drainage areas of the sites were assigned land-use designations according to the following definitions: Agriculture is greater than 40 percent crop and pasture, less than 40 percent forest, and less than 10 percent urban. Urban is less than 30 percent crop and pasture, population greater than 100 persons per square mile, and water withdrawals for domestic use greater than 6 million gallons per day. Forest is greater than 50 percent forest, less than 40 percent agriculture, and less than 10 percent urban. Range is greater than 50 percent range and barren land, less than 40 percent agriculture, less than 40 percent forest, and less than 10 percent urban.

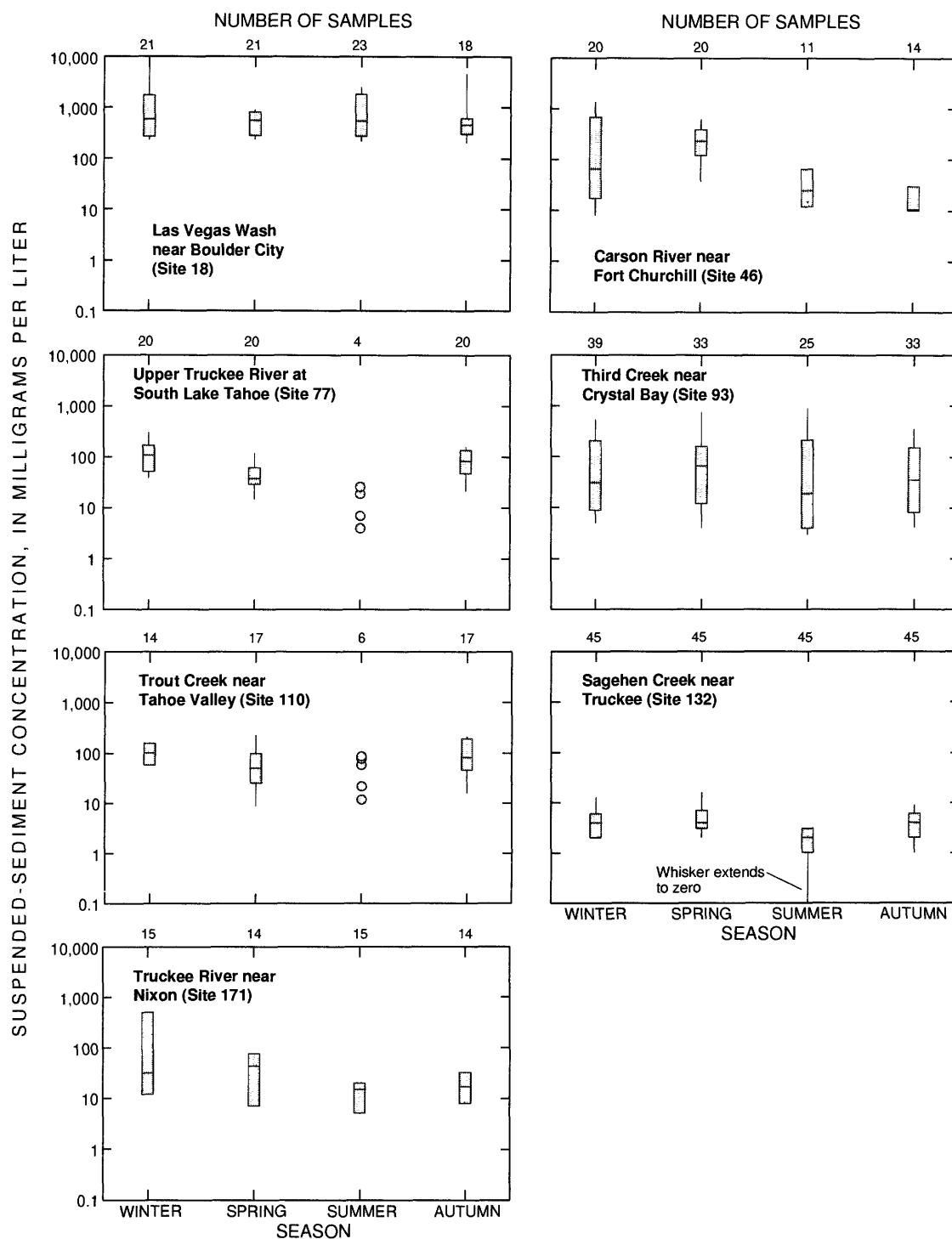


Figure 65. Seasonally normalized suspended sediment concentrations for selected sites during water year 1980 through April 1990. Numbers in parentheses are site numbers on plates 1 and 2 and in appendix A.

Table 15. Statistical summaries of seasonally normalized suspended-sediment concentrations by seasons for selected sites in Nevada Basin and Range NAWQA study unit, water year 1980 through April 1990

[--, 10th and 90th percentiles not shown if less than 15 samples; no percentiles shown if less than 10 samples]

Site name and number (app. A and pls. 1 and 2)	Season	Number of samples	Suspended-sediment concentration for indicated percentile (milligrams per liter)				
			10th	25th	50th (median)	75th	90th
Las Vegas Wash near Boulder City (18)	winter	21	234	270	582	1,750	6,070
	spring	21	237	283	558	822	900
	summer	23	220	278	550	1,810	2,570
	autumn	18	207	300	464	610	4,660
Carson River near Fort Churchill (46)	winter	20	8	17	66	686	1,380
	spring	20	38	124	236	390	635
	summer	11	--	12	25	66	--
	autumn	14	--	10	11	30	--
Upper Truckee River at South Lake Tahoe (77)	winter	20	39	51	107	168	302
	spring	20	15	29	38	61	118
	summer	4	--	--	--	--	--
	autumn	20	22	48	85	138	159
Third Creek near Crystal Bay (93)	winter	39	5	9	31	208	542
	spring	33	4	12	67	162	743
	summer	25	3	4	19	211	904
	autumn	33	4	8	35	154	359
Trout Creek near Tahoe Valley (110)	winter	14	--	58	103	160	--
	spring	17	9	25	51	101	228
	summer	6	--	--	--	--	--
	autumn	17	16	46	83	196	212
Sagehen Creek near Truckee (132)	winter	45	2	2	4	6	13
	spring	45	2	3	4	7	16
	summer	45	0	1	2	3	3
	autumn	45	1	2	4	6	9
Truckee River near Nixon (171)	winter	15	2	12	32	500	863
	spring	14	--	7	44	76	--
	summer	15	4	5	15	20	38
	autumn	14	--	8	17	32	--

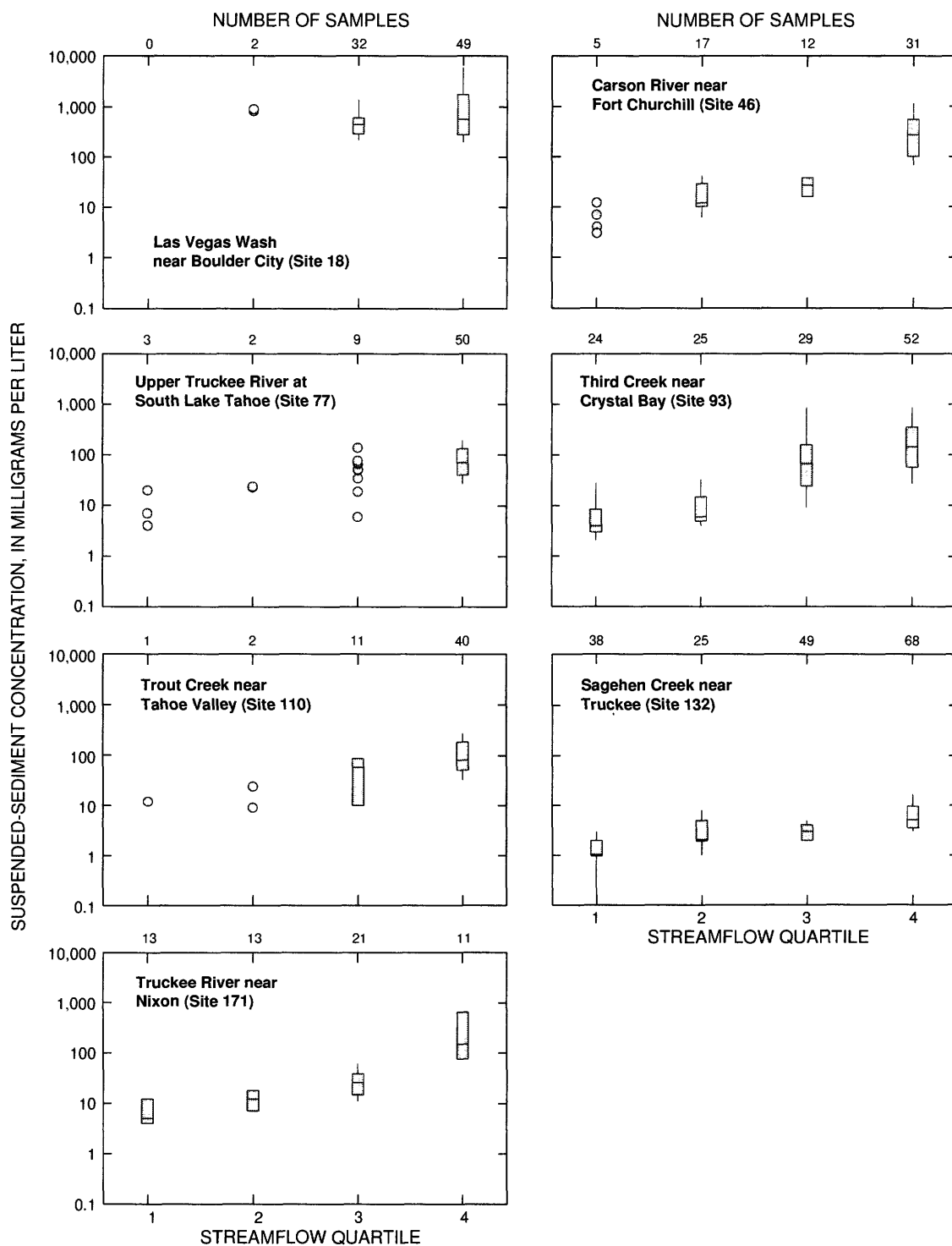


Figure 66. Seasonally normalized suspended-sediment concentrations (water year 1980 through April 1990) by streamflow quartiles (water year 1970 through April 1990) for selected sites. Numbers in parentheses are site numbers on plates 1 and 2 and in appendix A.

Table 16. Statistical summaries of seasonally normalized suspended-sediment concentrations (water year 1980 through May 1990) by streamflow quartiles (water year 1970 through April 1990) for selected sites, Nevada Basin and Range NAWQA study unit

[--, 10th and 90th percentiles not shown if less than 15 samples; no percentiles shown if less than 10 samples]

Sites name and map number (app. A and pls. 1 and 2)	Streamflow quartile ¹	Number of samples	Suspended-sediment concentration for indicated percentile (milligrams per liter)				
			10th	25th	50th (median)	75th	90th
Las Vegas Wash near Boulder City (18)	first	0	--	--	--	--	--
	second	2	--	--	--	--	--
	third	32	220	292	449	616	1,420
	fourth	49	201	278	570	1,750	6,070
Carson River near Fort Churchill (46)	first	5	--	--	--	--	--
	second	17	6	10	12	29	41
	third	12	--	16	27	38	--
	fourth	31	66	102	270	558	1,160
Upper Truckee River at South Lake Tahoe (77)	first	3	--	--	--	--	--
	second	2	--	--	--	--	--
	third	9	--	--	--	--	--
	fourth	50	27	40	72	134	196
Third Creek near Crystal Bay (93)	first	24	2	3	4	9	29
	second	25	4	5	6	15	35
	third	29	9	24	68	162	857
	fourth	52	26	57	144	357	893
Trout Creek near Tahoe Valley (110)	first	1	--	--	--	--	--
	second	2	--	--	--	--	--
	third	11	--	10	58	87	--
	fourth	40	32	50	81	189	274
Sagehen Creek near Truckee (132)	first	38	0	1	1	2	3
	second	25	1	2	2	5	8
	third	49	2	2	3	4	5
	fourth	68	3	4	5	10	17
Truckee River near Nixon (171)	first	13	--	4	5	12	--
	second	13	--	7	12	18	--
	third	21	11	15	26	38	60
	fourth	11	--	76	149	648	--

¹ The first quartile is the lowest 25th percentile of streamflow, the second quartile is the streamflow higher than the 25th percentile through the 50th percentile, the third quartile is the streamflow higher than the 50th percentile through the 75th percentile, and the fourth quartile is the streamflow higher than the 75th percentile through the 100th percentile.

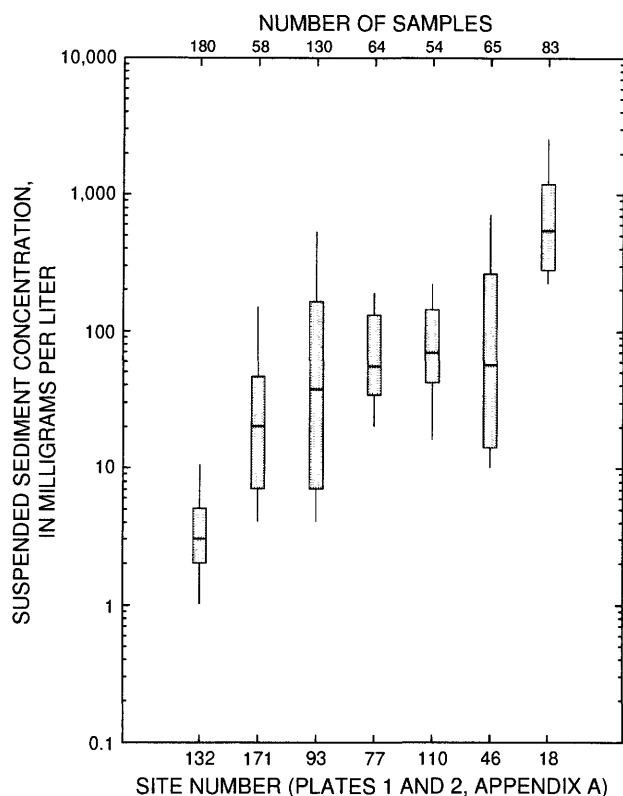


Figure 67. Suspended-sediment concentrations for selected sites for water year 1980 through April 1990.

If the criteria used by Smith and others (1993) are applied to the drainage areas of selected sediment sites used in this report, the watersheds of all the selected sites except Las Vegas Wash near Boulder City, the Carson River near Fort Churchill, and the Truckee River near Nixon are classified as forest. The watershed of the Las Vegas Wash site is classified as range,

although nearly all flow comes from the urban area. The watershed of the Carson River site has some components of agriculture and forest and has the most agricultural use of the selected sites. The watershed of the Truckee River site also has agriculture and forest, but the most significant aspect is the 11.6 percent open water. Lakes and impoundments in the watershed of this site probably trap significant amounts of suspended sediment. The median concentration of suspended sediment for those selected sites classified as forest ranged from 3 mg/L for Sagehen Creek near Truckee to 69 mg/L for Trout Creek near Tahoe Valley (table 17), but only two samples were collected from the Trout Creek site since October 1985; the national median for forest is 19 mg/L (table 19). The median concentration for the Las Vegas Wash site (which can be classified as urban) is 541 mg/L, much higher than the national urban median of 25 mg/L, but no samples have been collected from this site since October 1985.

Temporal Variability

The strong relation between streamflow and suspended-sediment concentration (fig. 68) is responsible for the seasonal patterns observed in figure 65. In general, the highest median concentrations of suspended sediment are observed during the spring when snowmelt runoff results in high rates of streamflow; lowest median concentrations generally are in the summer when the snowpack is depleted and streamflow rates are low. However, concentrations can be high during the winter and autumn because of snowmelt or rainfall runoff and during the summer because of thunderstorm

Table 17. Statistical summaries of seasonally normalized suspended-sediment concentrations for selected sites in Nevada Basin and Range NAWQA study unit, water year 1980 through April 1990

Site name and number (app. A and pls. 1 and 2)	Number of samples	Suspended-sediment concentration for indicated percentile (milligrams per liter)				
		10th	25th	50th (median)	75th	90th
Las Vegas Wash near Boulder City (18)	83	220	278	541	1,200	2,570
Carson River near Fort Churchill (46)	65	10	14	56	261	712
Upper Truckee River at South Lake Tahoe (77)	64	20	34	55	130	188
Third Creek near Crystal Bay (93)	130	4	7	37	162	533
Trout Creek near Tahoe Valley (110)	54	16	42	69	142	219
Sagehen Creek near Truckee (132)	180	1	2	3	5	11
Truckee River near Nixon (171)	58	4	7	20	46	149

Table 18. Land use for watersheds of selected sites, Nevada Basin and Range NAWQA study unit

[Land use computed from U.S. Geological Survey digital data, 1:250,000 scale, 1973-83]

Site name and number (app. A and pls. 1 and 2)	Land use (percent of watershed)							
	Urban	Agriculture	Range	Forest	Open water	Wetland	Barren	Tundra
Las Vegas Wash near Boulder City (18)	5.0	0.2	79.2	14.5	0.0	0.2	0.9	0.0
Carson River near Fort Churchill (46)	1.1	6.7	37.9	51.1	.1	.9	.9	1.3
Upper Truckee River at South Lake Tahoe (77)	4.4	.0	8.1	75.5	1.3	.2	10.0	.5
Blackwood Creek near Tahoe City (83)	1.1	.0	.0	98.9	.0	.0	.0	.0
Ward Creek at Highway 89 (84)	1.9	.0	.0	93.6	.0	.0	4.5	.0
Third Creek near Crystal Bay (93)	9.9	.0	6.1	72.2	.5	.0	3.8	7.5
Trout Creek near Tahoe Valley (110)	2.9	.0	3.5	89.4	.2	.0	.9	3.1
Sagehen Creek near Truckee (132)	0.0	.0	15.8	84.2	.0	.0	.0	.0
Truckee River near Nixon (171)	4.6	2.7	36.8	40.9	11.6	.7	2.2	.5

runoff. Flow at Las Vegas Wash near Boulder City is primarily treated sewage effluent and has little or no relation to season.

Long-term trends in suspended-sediment concentrations for the Carson River near Fort Churchill and the Truckee River near Nixon during water years 1980-89 were evaluated by Seiler (1993). His analysis showed no trends in suspended-sediment concentrations. Although data are insufficient for Las Vegas Wash near Boulder City, increasing annual streamflow from urban runoff and treated sewage effluent could be causing increasing suspended-sediment concentrations.

SUSPENDED-SEDIMENT LOADS

Suspended-sediment loads can be used to determine the amount of suspended sediment in transport at a given site, the rate of erosion in upstream areas, and the amount of sediment available for deposition in downstream channels, canals, wetlands, or impoundments. Normalizing suspended-sediment loads to a unit area (termed sediment yield) allows direct comparison of upstream erosion among stream sites and watersheds. Differences in yields can be a result of environmental factors (including precipitation, soil, slope, and vegetation) or human effects (including land use and streamflow regulation by impoundments, diversions,

Table 19. Nationwide annual suspended-sediment yields and statistical summary of suspended-sediment concentrations for streams draining selected land uses, water years 1980-89 (Smith and others, 1993, p. 130)

Land-use category	Annual suspended-sediment yield (tons per square mile)	Suspended-sediment concentration for indicated percentile (milligrams per liter)				
		10th	25th	50th (median)	75th	90th
Urban	23	4	12	25	115	229
Agriculture		21	52	131	291	654
Wheat	10					
Corn and soybeans	100					
Mixed	79					
Range	33	19	93	230	955	2,710
Forest	31	5	9	19	43	99

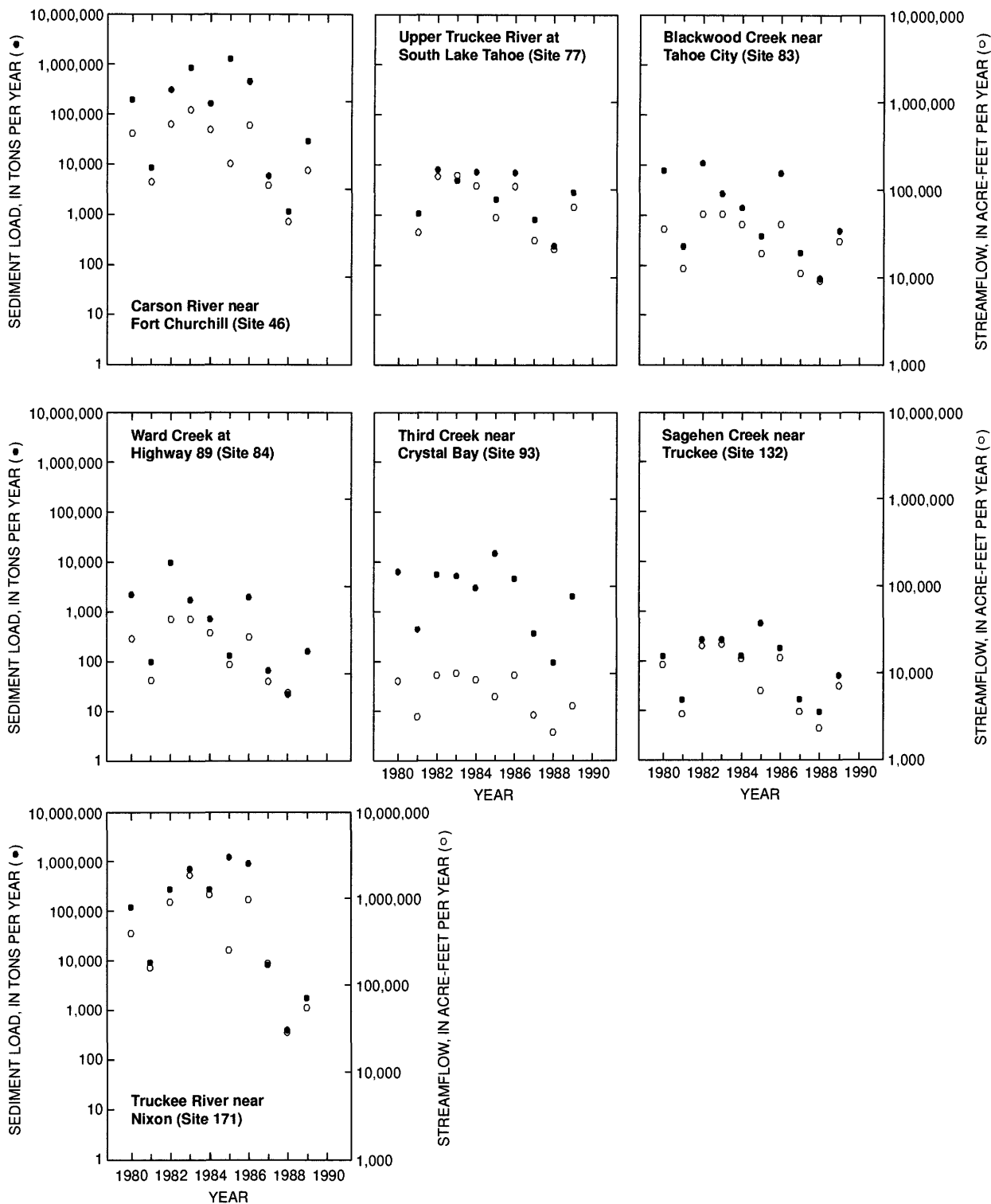


Figure 68. Streamflow and suspended-sediment loads for selected sites, water years 1980-89. Numbers in parentheses are site numbers on plate 2 and in appendix A.

Table 20. Regression models used to estimate natural logarithm of daily sediment loads

[The regression model is of the form: $\ln \text{Load} = a + b \ln(Q) + c(\ln(Q))^2 + d \sqrt{Q} + eT + fT^2 + g \sin(2\pi T) + h \cos(2\pi T)$, where Load is sediment load in tons per day; Q, streamflow in cubic feet per second; T, is adjusted decimal time, calculated by dividing day of year by number of days in year and adding year minus 1900. Symbol and abbreviations: --, term was not included in the model; r^2 , coefficient of determination, amount of variance in $\ln \text{Load}$ accounted for by independent variables; CV, coefficient of variation, defined as root mean square divided by mean and expressed as percent]

Site name and number (app. A and pl. 2)	Constants in equation								Regression statistics	
	a	b	c	d	e	f	g	h	r^2	CV
Carson River near Fort Churchill (46)	-2.86	--	0.218	-0.0468	--	--	--	-0.317	0.97	13.0
Third Creek near Crystal Bay (93)	263	4.06	-.354	--	-6.39	0.0378	-0.416	--	.77	-498
Sagehen Creek near Truckee (132)	-5.29	1.08	.0629	--	--	--	--	.333	.90	-26.3
Truckee River near Nixon (171)	185	1.16	--	.0527	-4.49	.0265	--	--	.96	24.5

and effluent discharges). Suspended-sediment loads were computed for selected sites by using equations developed from multiple regression analysis. The equations and associated constants, coefficients of determination (r^2), and coefficients of variation (CV) are presented in table 20 for Carson River near Fort Churchill (site 46, pl. 2), Third Creek near Crystal Bay (site 93), Sagehen Creek near Truckee (site 132), and Truckee River near Nixon (site 171). The independent variables in the equations are streamflow and time terms. The coefficient of determination is the fraction of variation in the dependent variable (sediment load) that is explained by the equation. The coefficient of variation is the standard error of the regression divided by the means of the dependent variable, expressed as a percent; dividing by the means allows relative comparisons among the equations. Periods of record for Las Vegas Wash near Boulder City (site 18, pl. 1) and Trout Creek near Tahoe Valley (site 112, pl. 2) were not adequate for developing representative equations: zero and two samples, respectively, were collected since water year 1985.

Transport

Streamflow is used in the computation of suspended-sediment loads and is a principal factor in determining the magnitude of suspended-sediment transport. Figure 68 illustrates the direct relation between streamflow rates and suspended-sediment transport. The largest annual suspended-sediment loads during water years 1980-89 generally were transported during water years 1980, 1982-84, and 1986;

those years also have the greatest annual streamflow rates (fig. 68). The Carson River near Fort Churchill (site 46, pl. 2) and the Truckee River near Nixon (site 171, pl. 2) transported the largest median annual loads of suspended sediment (180,000 and 200,000 tons, table 21) and had the largest median annual streamflow volumes (315,000 and 332,000 acre-ft, table 21).

Additional suspended-sediment load data have been published for a few long-term California sites in the Lake Tahoe Basin. These sites—Upper Truckee River at South Lake Tahoe (site 77), Blackwood Creek near Tahoe City (site 83), and Ward Creek at Highway 89 (site 84)—are operated to provide information on the transport of nutrients and suspended sediment to Lake Tahoe. Water samples for analysis of suspended-sediment concentration were collected frequently at these sites (daily or more frequently during spring runoff or rapidly changing periods of flow and every 5 to 10 days during low flow conditions). If samples were collected more frequently than daily, time-discharge weighted averages were used to compute the daily load. Suspended-sediment loads transported during periods when samples were not collected were estimated by using streamflow, suspended-sediment concentrations measured before and after the period, and suspended-sediment loads measured during other periods of similar streamflow. Statistical summaries of annual and seasonal streamflow and suspended-sediment loads and yields for these sites are in table 21. Suspended-sediment transport generally is greatest during the spring when snowmelt runoff causes high rates of streamflow and least during summer low flow;

however, large loads of suspended sediment also can be transported during the winter because of snowmelt or rainfall runoff (fig. 69 and table 21).

Yields

Before suspended-sediment loads can be compared for drainage areas of different sizes, they need to be normalized to a unit area. The resultant suspended-sediment yields can then be related to conditions in the watersheds. Median annual and seasonal suspended-sediment yields for the selected sites and USGS sites operated by the California District with 10 years or seasons of record are given in table 21.

Sagehen Creek near Truckee (site 132 on pl. 2) has a much smaller median annual suspended-sediment yield (12 ton/mi²) than any other site. This headwater Hydrologic Benchmark site is not affected by urban or agricultural activities (table 18). The site with the highest percentage of drainage area in urban land use (9.9 percent), Third Creek near Crystal Bay (site 93), had a much larger annual yield (630 ton/mi²) than any other site. However, two avalanches in this basin in February 1986 (Timothy G. Rowe, U.S. Geological Survey, oral commun., 1993) could have affected the sediment yields. The Truckee River near Nixon (site 171) has an annual suspended-sediment yield of 110 ton/mi². The Carson River near Fort Churchill (site 44) has the most agricultural land in its drainage area (6.7 percent) and the second highest annual suspended-sediment yield (140 ton/mi²).

Smith and others (1993) determined that the average 10-year (water years 1980-89) median flow-adjusted yield of suspended sediment for stations in the Great Basin was about 21 ton/mi² and that the yield had decreased at 0.2 percent per year. This yield is in the range of those determined for the Sagehen Creek site and the Ward Creek site (site 84), but is much smaller than those determined for the other sites. National suspended-sediment yields for agriculture (wheat, corn and soybeans, and mixed), range, and forest are listed in table 19. Suspended-sediment yields computed for this investigation do not agree well with those by Smith and others (1993). On a national basis, urban land-use areas had the second smallest suspended-sediment yield; however, urban land use and activities possibly cause some of the largest suspended-sediment yields in the Nevada Basin and Range study unit.

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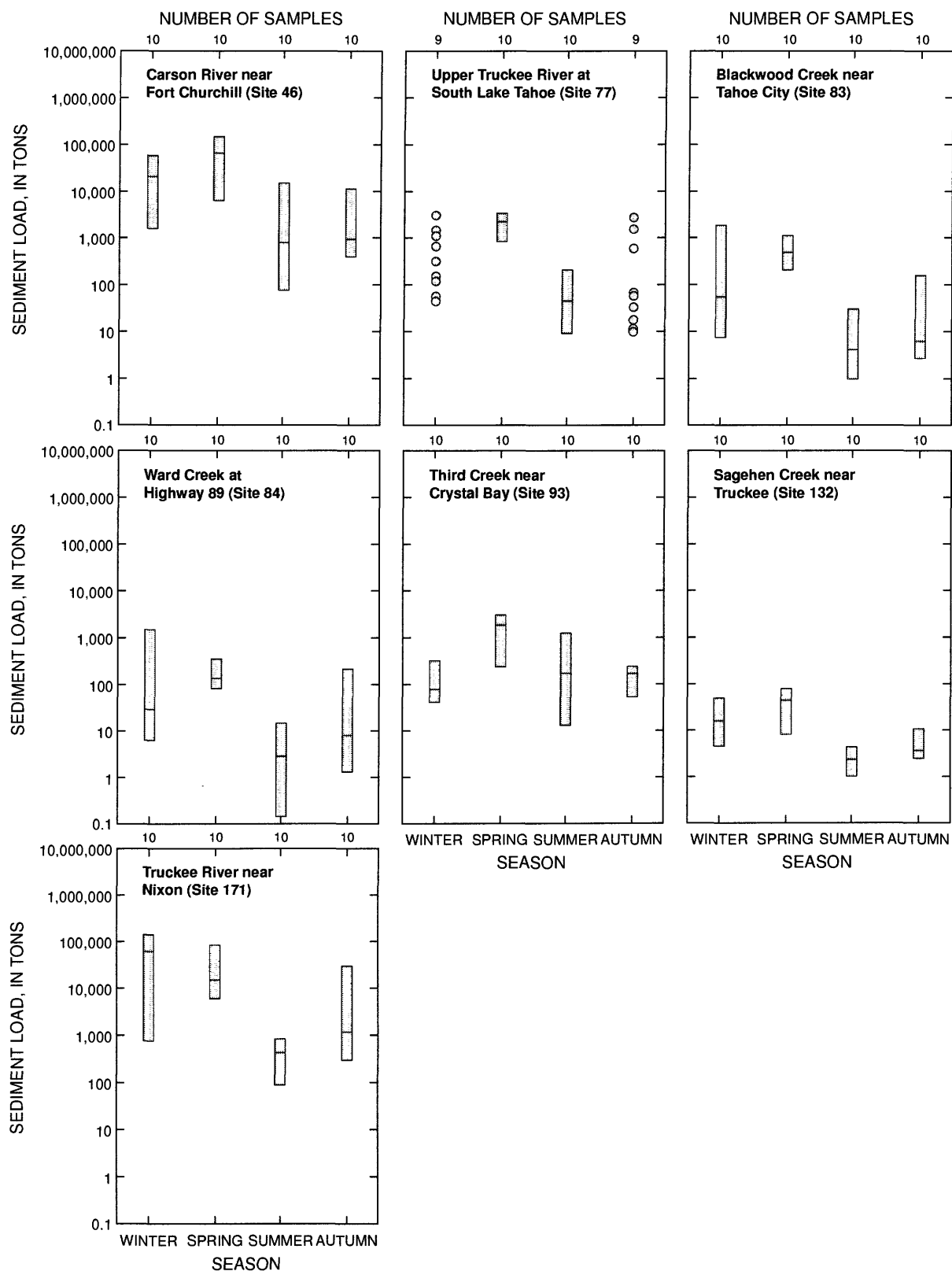


Figure 69. Seasonal suspended-sediment loads for selected sites, water years 1980-89. Numbers in parentheses are sites numbers on plate 2 and in appendix A.

Table 21. Statistical summaries of annual and seasonal suspended-sediment loads, median streamflow, and median suspended-sediment yields for selected sites in Nevada Basin and Range NAWQA study unit, water years 1980-89

[Values not shown if less than 10 years or seasons of record]

Site name and number (app. A and pl. 2)	Period	Suspended-sediment load for indicated percentile (tons)			Median total streamflow for indicated period (acre-feet)	Median suspended- sediment yield (tons per square mile)
		25th	50th (median)	75th		
Carson River near Fort Churchill (46)	annual	8,500	180,000	450,000	315,000	140
	winter	1,600	21,000	60,000	78,900	16
	spring	6,400	66,000	140,000	159,000	51
	summer	75	770	14,000	9,710	0.59
	autumn	380	930	11,000	30,900	0.71
Upper Truckee River at South Lake Tahoe (77) ¹	annual	--	--	--	--	--
	winter	--	--	--	--	--
	spring	900	2,300	3,600	49,500	42
	summer	9.4	48	220	4,810	0.87
	autumn	--	--	--	--	--
Blackwood Creek near Tahoe City (83) ¹	annual	240	960	6,900	31,200	86
	winter	8.5	62	2,100	5,000	5.5
	spring	230	560	1,200	20,100	50
	summer	1.1	4.3	33	1,430	0.38
	autumn	2.8	6.5	170	1,120	0.58
Ward Creek at Highway 89 (84) ¹	annual	99	440	2,000	22,000	45
	winter	6.9	32	1,700	3,480	3.3
	spring	89	140	380	14,100	14
	summer	0.15	3.0	16	829	0.31
	autumn	1.3	8.4	230	866	0.86
Third Creek near Crystal Bay (93)	annual	440	3,800	5,600	6,900	630
	winter	46	86	360	825	14
	spring	260	2,100	3,500	3,540	350
	summer	14	180	1,400	1,030	30
	autumn	54	180	260	861	30
Sagehen Creek near Truckee (132)	annual	17	130	270	9,900	12
	winter	4.9	18	55	1,780	1.7
	spring	8.7	48	85	5,930	4.6
	summer	1.0	2.4	4.5	755	0.23
	autumn	2.6	3.8	11	770	0.36
Truckee River near Nixon (171)	annual	8,200	200,000	740,000	332,000	110
	winter	760	63,000	140,000	102,000	34
	spring	6,200	15,000	86,000	162,000	8.2
	summer	88	420	830	15,700	0.23
	autumn	290	1,200	29,000	40,800	0.65

¹ Computed from loads published by the USGS California District.

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Appendix A. Selected surface-water sites with available pesticide (water years 1966-92), nutrient (water year 1970 through April 1990), or suspended-sediment (water year 1970 through April 1990) analyses for the Las Vegas Valley area and the Carson and Truckee River Basins

Constituent: N, nutrient data; P, pesticide data; S, suspended-sediment data.

Matrix sampled: B, bed sediment; F, fish tissue; W, water.

[Abbreviations and symbols: BMI, Basic Management Incorporated; BOR, U.S. Bureau of Reclamation; CCWD, Carson City Water Department; CDHS, California Department of Health Services; CDWR, California Department of Water Resources; CWRCB, California Water Resources Control Board; IVGID, Incline Village General Improvement District; NBCHP, Nevada Bureau of Consumer Health Protection Services; NDEP, Nevada Division of Environmental Protection; STP, Sewage Treatment Plant; USEPA, U.S. Environmental Protection Agency; USFS, U.S. Forest Service; USFWS, U.S. Fish and Wildlife Service; USGS, U.S. Geological Survey; USPHS, U.S. Public Health Service; --, not available. Only one site number, name, and location is given for sites that were determined to be equivalent.]

Site number (pls. 1 and 2)	Site identification	Site name	Drainage area (square miles)		Location		Agency	Con- sti- tuent	Period of record	Number of samples	Matrix sampled
					Latitude	Longitude					
Las Vegas Valley area											
1	LV-2	Las Vegas STP effluent	--	360747	1150203	USPHS	P	1966	1	W	
2	CC1	Clark County STP effluent	--	360641	1150139	USPHS	P	1966	1	W	
3	1	Las Vegas Wash below STP	--	360631	1150121	BOR	P	1983	1	W	
	W-4					USPHS	P	1966	1	W	
4	2A	STP effluent channel	--	360614	1150101	BOR	P	1983	1	W	
5	2B	Las Vegas Wash Marsh	--	360549	1150050	BOR	P	1983	1	W	
6	MRF	Monson Road Floodway	--	360628	1150221	BOR	P	1983	1	W	
7	TAF	Tropicana Avenue Floodway	--	360601	1150152	BOR	P	1983	1	W	
8	360508115020001	Duck Creek	--	360508	1150201	BOR	P	1983	1	W	
9	H-7	Henderson STP effluent	--	360427	1150010	USPHS	P	1966	1	W	
10	GWD	Drainage ditch at Pabco Road	--	360510	1145906	BOR	P	1983	1	W	
11	360510114472001	Lower BMI Pond	--	360511	1145907	USEPA	P	1982	1	W	
	--					USPHS	P	1966	1	W	
12	2	Las Vegas Wash marsh	--	360526	1145906	BOR	P	1983	1	W	
13	09419700	Las Vegas Wash near Henderson	1,518	360520	1145905	USGS	N	1970-90	199	W	
	09419700					USGS	S	1977-85	100	W	
	--					USPHS	P	1966	1	W	
14	3	Las Vegas Wash marsh	--	360519	1145903	BOR	P	1983	1	W	
15	3A	Las Vegas Wash marsh	--	360523	1145829	BOR	P	1983	1	W	
16	AD	Alpha ditch at Boulder Highway	--	360302	1145933	BOR	P	1983	1	W	
17	4	Las Vegas Wash	--	360611	1145556	BOR	P	1983	1	W	

Appendix A. Selected surface-water sites with available pesticide (water years 1966-92), nutrient (water year 1970 through April 1990), or suspended-sediment (water year 1970 through April 1990) analyses for the Las Vegas Valley area and the Carson and Truckee River Basins—Continued

Site number (pls. 1 and 2)	Site identification	Site name	Drainage area, (square miles)	Location		Agency	Con- sti- tuent	Period of record	Number of samples	Matrix sampled	
				Latitude	Longitude						
Las Vegas Valley area—Continued											
18	09419800	Las Vegas Wash near Boulder City	1,586	360720	1145415	USGS	P	1974-80	22	W	
	09419800					USGS	S	1974-85	163	W	
	360720114541501					USEPA	P	1983-84	4	WBF	
	5					BOR	P	1983	1	W	
	W-11					USPHS	P	1966	1	W	
19	36074811452001	Lake Mead, Las Vegas Bay	--	360748	1145200	USEPA	P	1979	1	WBF	
	LVB-1					USPHS	P	1966	1	W	
	LVB-2					USPHS	P	1966	1	W	
	LVB-3					USPHS	P	1966	1	W	
	LVB-4	USPHS	P	1966	1	W					
	LVB-6					USPHS	P	1966	1	W	
	LVB-7					USPHS	P	1966	1	W	
	LVB-12					USPHS	P	1966	1	W	
20	360408144753001	Henderson city water supply	--	360408	1144753	USEPA	P	1975	1	W	
21	92	Lake Mead	--	360300	1144730	USFWS	P	1970-84	6	F	
22	--	Lake Mead, Boulder Beach	--	360300	1144700 ¹	NBCHP	P	1983-91	2	W	
23	360815114425301	Lake Mead, Callville Bay	--	360815	1144253	USEPA	P	1979	1	WB	
	--	Callville Bay, water system				NBCHP	P	1986	1	W	
Carson River Basin											
24	--	East Fork Carson River near Markleeville	--	384040	1194430	CWRCB	P	1982-86	2	F	
25	10309000	East Fork Carson River near Gardnerville	356	385050	1194210	USGS	N	1979-90	20	W	
26	385247119412301	Carson River at Riverview Trailer Park	--	385247	1194123	NDEP	N	1970-90	225	W	
27	385252120022301	Carson River at Riverview	--	385303	1194140	USEPA	P	1981-82	2	W	
28	384450119464001	Indian Creek Reservoir	--	384450	1194640	USEPA	P	1983	1	W	
29	385646119464301	East Fork Carson River at State Route 88	--	385646	1194643	NDEP	N	1975-90	149	W	
30	385815119475301	East Fork Carson River at Muller Lane	--	385815	1194753	NDEP	N	1970-90	215	W	
31	10310000	West Fork Carson River at Woodfords	65.4	384610	1194955	USGS	N	1974-90	42	W	
	384610119500001					CDWR	N	1986	2	W	

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Site number (pls. 1 and 2)	Site identification	Site name	Drainage area, (square miles)	Location		Agency	Con- sti- tuent	Period of record	Number of samples	Matrix sampled
				Lati- tude	Longi- tude					
Carson River Basin—Continued										
32	384832119463301	West Fork Carson River at Paynesville	--	384832	1194633	NDEP	N	1970-90	223	W
33	385816119490001	West Fork Carson River at Muller Lane	--	385816	1194900	NDEP	N	1975-90	147	W
34	385815119500401	West Brockliss Slough at Muller Lane	--	385815	1195004	NDEP	N	1970-90	218	W
35	385920119492601	Carson River at Brockliss Slough	--	385920	1194926	USEPA	P	1989	1	W
36	390046119481701	Williams Slough near Genoa	--	390046	1194817	USGS	P	1987	1	B
37	10310450	Carson River at Cradlebaugh Bridge	--	390252	1194644	USGS	N	1988	1	W
	390252119464301					NDEP	N	1970-90	171	W
38	390558119433001	Carson River at McTarnahan Bridge	--	390558	1194333	NDEP	N	1975-90	152	W
39	390630119424001	Carson River at Mexican Dam	--	390630	1194240	USEPA	P	1981	1	W
40	--	Kings Canyon Creek near Carson City	4.06	390914	1194824	CCWD	P	1978-89	4	W
41	--	Ash Canyon Creek near Carson City	5.20	391035	1194816	CCWD	P	1978	1	W
42	391052119414101	Carson River at Deer Run Road	958	391052	1194141	NDEP	N	1970-90	222	W
43	391053119414001	Carson River at New Empire	--	391053	1194140	USEPA	P	1980	1	WBF
44	391118119393001	Carson River at Brunswick Canyon	--	391118	1193930	USEPA	P	1981	1	WBF
45	391412119351301	Carson River at Como Road, Dayton	--	391412	1193513	NDEP	N	1975-90	167	W
46	10312000	Carson River near Fort Churchill	1,302	391730	1191840	USGS	P	1970-92	3	B
	10312000					USGS	N	1970-90	145	W
	10312000					USGS	S	1975-90	128	W
	391734119184001					USEPA	P	1981-83	2	WBF
	391730119184101					NDEP	N	1970-90	137	W
47	--	Carson River at Lahontan Dam	1,799	392745	1190400	USEPA	P	1980	1	WBF
48	10312150	Carson River below Lahontan Reservoir	1,801	392750	1190245	USGS	P	1987	1	B
						USGS	N	1979-89	34	W
49	10312165	Sheckler Reservoir at Outlet	--	392544	1185421	USGS	P	1987	1	B
50	--	L Drain	--	392645	1185421	NDEP	P	1987	1	W
51	10312180	Carson Lake Drain above Carson Lake	--	392038	1184437	USGS	P	1987	1	B

Appendix A. Selected surface-water sites with available pesticide (water years 1966-92), nutrient (water year 1970 through April 1990), or suspended-sediment (water year 1970 through April 1990) analyses for the Las Vegas Valley area and the Carson and Truckee River Basins—Continued

Site number (pls. 1 and 2)	Site identification	Site name	Drainage area, (square miles)	Location		Agency	Con- sti- tuent	Period of record	Number of samples	Matrix sampled
				Latitude	Longitude					
Carson River Basin—Continued										
52	391951118445001	Carson Lake Sprig Pond Unit	--	391951	1184450	USGS	P	1987	1	B
53	39174311842430C	Carson Lake Big Water Unit	--	391743	1184243	USGS	P	1987	1	B
54	392108118413501	Carson Lake Island Unit	--	392108	1184135	USGS	P	1987	1	B
55	--	L Deep Drain	--	392315	1184240	NDEP	P	1987	1	W
56	--	Diagonal Drain at Highway 50	--	392433	1183937	USEPA	P	1989	1	W
57	10312215	Stillwater Point Diversion Drain	--	392929	1183222	USGS	P	1987	1	B
58	392950118315201	Stillwater Point Reservoir south	--	392950	1183152	USGS	P	1987	1	B
59	393154118285401	Stillwater Point Reservoir north	--	393054	1183038	USGS	P	1987	1	B
60	10312218	Stillwater Slough at Stillwater	--	393117	1183247	USGS	P	1987	1	B
61	1031221920	Hunter Drain at Division Road	--	393554	1182838	USGS	P	1987	1	B
62	1031221930	Lead Lake Canal at Hunter Road	--	393624	1182919	USGS	P	1987	1	B
63	393601118255401	Cattail Lake at outlet	--	393601	1182554	USGS	P	1987	1	B
64	393546118223301	East Alkali Lake at outlet	--	393546	1182333	USGS	P	1987	1	B
65	10312270	Paute Drain at Wildlife Refuge	--	393633	1183319	USGS	P	1987	1	B
66	10312274	TJ Drain at Wildlife Refuge	--	393632	1183314	USGS	P	1987	1	B
67	393654118315501	Lead Lake at Millens Landing	--	393654	1183155	USGS	P	1987	1	B
68	393643118310501	South Lead Lake	--	393643	1183105	USGS	P	1987	1	B
69	393713118254001	Goose Lake at Goose Landing	--	393713	1182540	USGS	P	1987-88	2	B
70	393907118263101	Swan Check Dam near outlet	--	393907	1182631	USGS	P	1987	1	B
71	394115118253201	Pintail Bay, near center	--	394115	1182532	USGS	P	1987	1	B
72	394824118435701	Carson Sink north of Humboldt Slough	--	394802	1184338	USGS	P	1987	1	B
73	394802118433801	Carson Sink south of Humboldt Slough	--	394824	1184357	USGS	P	1987	1	B
Truckee River Basin										
74	384730120002501	Big Meadow Creek above Cookhouse Meadow	--	384730	1200025	USFS	N	1978-90	146	W
75	384740120003001	Grass Lake Creek above campground	--	384740	1200030	USFS	S	1980-90	130	W
						USFS	N	1980-90	154	W
						USFS	S	1980-90	135	W

Appendix A. Selected surface-water sites with available pesticide (water years 1966-92), nutrient (water year 1970 through April 1990), or suspended-sediment (water year 1970 through April 1990) analyses for the Las Vegas Valley area and the Carson and Truckee River Basins—Continued

Site number (pls. 1 and 2)	Site identification	Site name	Drainage area, (square miles)	Location		Agency	Con- sti- tuent	Period of record	Number of samples	Matrix sampled
				Latitude	Longitude					
Truckee River Basin—Continued										
76	385329120012501	Sawmill Pond Creek above project	--	385329	1200125	USFS	N	1985-89	70	W
77	10336610	Upper Truckee River at South Lake Tahoe	54.9	385522	1195923	USFS	S	1986-89	49	W
						USGS	N	1970-89	24	W
78	390048120093001	Meeks Creek above Girl Scout Camp	--	390048	1200930	USGS	S	1972-90	169	W
						USFS	N	1979-90	153	W
79	390210120073501	Meeks Creek near Tahoe City	--	390210	1200735	USFS	S	1978-90	114	W
						USGS	N	1984-89	18	W
80	10336645	General Creek near Meeks Bay	7.44	390307	1200703	USGS	S	1981-89	38	W
						USFS	N	1978-90	140	W
81	390600120122001	Blackwood Canyon	--	390600	1201220	USFS	S	1978-90	109	W
						USGS	N	1978-90	109	W
82	390625120113091	Blackwood Creek below ponds	--	390625	1201130	USFS	N	1978-90	169	W
						USFS	S	1978-90	133	W
83	10336660	Blackwood Creek near Tahoe City	11.2	390627	1200940	USGS	N	1983-89	23	W
						USGS	S	1974-90	150	W
84	10336676	Ward Creek at Highway 89	9.7	390756	1200924	USGS	N	1984-89	27	W
						USGS	S	1973-89	154	W
85	391440120022002	Snow Creek below Highway 28	--	391440	1200220	USFS	S	1986-90	39	W
						USFS	N	1986-90	77	W
86	391435120014501	Griff Creek above Highway below pond	--	391435	1200145	USFS	S	1986-90	38	W
						USFS	N	1985-90	94	W
87	39142112014701	Griff Creek above sediment pond	--	391421	1200147	USFS	S	1986-90	63	W
						USFS	N	1986-90	63	W
88	391503119583901	Second Creek at Second Creek Drive	--	391503	1195839	NDEP	N	1970-90	104	W
						NDEP	N	1970-90	107	W
89	391500119583701	Second Creek at Lakeshore Boulevard	--	391500	1195837	NDEP	N	70-90	107	W
						NDEP	N	70-90	107	W
90	391438119572901	Wood Creek at Lakeshore Boulevard	--	391438	1195729	IVGID	P	90	1	W
						IVGID	P	90	1	W
91	--	SW-2	--	391623	1195651	NDEP	N	70-90	101	W
						NDEP	N	70-90	101	W
92	391550119472701	East Fork Third Creek at State Route 431	--	391551	1195639	NDEP	N	70-90	101	W
						NDEP	N	70-90	101	W

Appendix A. Selected surface-water sites with available pesticide (water years 1966-92), nutrient (water year 1970 through April 1990), or suspended-sediment (water year 1970 through April 1990) analyses for the Las Vegas Valley area and the Carson and Truckee River Basins—Continued

Site number (pls. 1 and 2)	Site identification	Site name	Drainage area, (square miles)	Location		Agency	Con- sti- tuent	Period of record	Number of samples	Matrix sampled
				Lati- tude	Longi- tude					
Truckee River Basin—Continued										
93	10336698 10336698 --	Third Creek near Crystal Bay	6.05	391426	1195644	USGS USGS USFS	N S N	70-90 70-90 70-90	133 387 101	W W W
94	391553119563401	West Fork Incline Creek at Highway 431	--	391553	1195634	NDEP	N	70-90	91	W
95	391424119563901	Incline Creek at Lakeshore Boulevard	--	391424	1195639	NDEP	N	70-90	102	W
96	10336700	Incline Creek near Crystal Bay	7.00	391425	1195638	USGS	N	70-90	133	W
97	--	Incline Creek, Incline District	--	391400	1195600 ^a	USGS	S	70-90	288	W
98	--	Marlette Lake	2.86	391022	1195415	NBCHP	P	78-85 79	2 1	W W
99	390945119552207	Marlette Creek tributary below campground	--	390945	1195527	USFS	N	78-89	99	W
100	390926119555301	Marlette Creek at mouth	--	390926	1195553	USFS	S	78-89	67	W
101	--	Trelease Creek	--	390900	1195300 ^a	USFS	N	78-89	143	W
102	10336730	Glenbrook Creek at Glenbrook	4.07	390515	1195620	USFS	S	78-89	13	W
103	10336740	Logan House Creek near Glenbrook	2.08	390400	1195604	NBCHP	P	79	1	W
104	--	Zephyr Creek near mouth	--	390025	1195653	USGS	N	72-90	101	W
105	10336765	Edgewood Creek at Lake Tahoe	--	385805	1195654	USGS	S	89-90	45	W
106	10336770 10336770 385145120040001	Trout Creek at USFS Road 12N01	7.40	385148	1195726	USGS	S	1984-90	57	W
107	385215119590001	Saxon Creek above landfill	--	385215	1195900	USGS	N	1988-90	90	W
108	385230119590501	Saxon Creek below landfill	--	385230	1195905	USGS	P	1985-89	2	W
109	385430119574002	Cold Creek Plant 09-002	--	385430	1195740	USFS	N	1984-90	2	W
						USFS	S	1984-90	52	W
						USFS	N	1984-90	62	W
						USFS	S	1984-90	63	W
						USFS	N	1990	6	W
						USFS	S	1990	5	W
						USFS	S	1981-90	124	W
						USFS	N	1979-90	123	W
						USFS	S	1979-90	132	W
						USFS	N	1976-90	62	W
						USFS	S	1977-90	68	W
						CDHS	P	1986	1	W

Appendix A. Selected surface-water sites with available pesticide (water years 1966-92), nutrient (water year 1970 through April 1990), or suspended-sediment (water year 1970 through April 1990) analyses for the Las Vegas Valley area and the Carson and Truckee River Basins—Continued

Site number (pls. 1 and 2)	Site identification	Site name	Drainage area, (square miles)	Location		Agency	Con- sti- tuent	Period of record	Number of samples	Matrix sampled	
				Latitude	Longitude						
Truckee River Basin—Continued											
110	10336780	Trout Creek near Tahoe Valley	36.7	385512	1195817	USGS	N	1983-88	4	W	
111	385530119545001	Left Fork Heavenly Valley Creek	--	385530	1195450	USFS	N	1980-90	168	W	
112	385530119551501	Heavenly Valley Creek near Sky Chair	--	385530	1195515	USFS	S	1980-89	135	W	
						USFS	S	1980-90	140	W	
						USFS	N	1976-90	150	W	
113	385522119560001	Heavenly Valley Creek below Patsy	--	385522	1195600	USFS	S	1980-90	150	W	
						USFS	N	1976-90	163	W	
114	10336790	Trout Creek at South Lake Tahoe	40.4	385556	1195840	USFS	N	1971-77	24	W	
115	385555119584001					USGS	S	1972-90	33	W	
	--	Lake Tahoe, Edgewood Water Company	504	385700	1195700 ^a	NBCHP	P	1977-86	8	W	
116	--	Lake Tahoe, Kingsbury District	504	385800	1195700 ^a	NBCHP	P	1977-89	8	W	
117	--	Lake Tahoe, Elk Point Water Company	504	385900	1195700 ^a	NBCHP	P	1978-89	5	W	
	--	Lake Tahoe, Round Hill District	504	385900	1195700 ^a	NBCHP	P	1972-89	7	W	
118	385912119572801	Lake Tahoe at Elk Point	504	385912	1195728	USEPA	P	1981	1	W	
119	--	Lake Tahoe, Cave Rock Water Company	504	390100	1195700 ^a	NBCHP	P	1979	1	W	
	--	Lake Tahoe, Skyland Water Company no. 1	504	390100	1195700 ^a	NBCHP	P	1972-89	6	W	
120	--	Lake Tahoe, Glenbrook Water Company	504	390700	1195700 ^a	NBCHP	P	1980-89	4	W	
121	391150119560001	Lake Tahoe at Sand Harbor	504	391150	1195600	NDEP	P	1980	1	W	
122	--	Lake Tahoe, Incline District-Washoe	504	391400	1195500 ^a	NBCHP	P	1980	1	W	
123	--	Lake Tahoe, Incline District	504	391400	1195700	NBCHP	P	1978-85	3	W	
124	--	Lake Tahoe, Crystal Bay Water Company	504	391400	1195900	NBCHP	P	1978	1	W	
125	10337500	Truckee River at Tahoe City	507	390959	1200836	USGS	P	1980	1	B	
	390959120083701	Truckee River at Tahoe City	507	390959	1200836	USEPA	P	1976	1	W	
126	10338000	Truckee River near Truckee	552	391717	1201230	USGS	P	1980	1	B	
127	10339000	Donner Creek near Truckee	29.4	391915	1201210	USGS	P	1980	1	B	

Appendix A. Selected surface-water sites with available pesticide (water years 1966-92), nutrient (water year 1970 through April 1990), or suspended-sediment (water year 1970 through April 1990) analyses for the Las Vegas Valley area and the Carson and Truckee River Basins—Continued

Site number (pls. 1 and 2)	Site identification	Site name	Drainage area, (square miles)	Location		Agency	Con- sti- tuent	Period of record	Number of samples	Matrix sampled
				Latitude	Longitude					
Truckee River Basin—Continued										
128	10339250	Martis Creek at U.S. Highway 267	25.8	391808	1200713	USGS	P	1973	1	B
						USGS	N	1973-90	53	W
129	10339380	Martis Creek Lake near Truckee	40	391938	1200648	USGS	S	1973-90	44	W
						USGS	P	1973	1	W
130	10339400	Martis Creek near Truckee	40	391944	1200700	USGS	P	1973	1	W
						USGS	N	1973-90	55	W
						USGS	S	1973-90	47	W
131	10339405	Martis Creek at Truckee River	--	392056	1200702	USGS	P	1980	1	B
132	10343500	Sagehen Creek near Truckee	10.5	392554	1201413	USGS	N	1970-90	51	W
						USGS	S	1971-90	630	W
133	--	Truckee River near Hirshdale	--	392205	1200430	CWRCB	P	1980-87	2	F
134	10344992	Truckee River near Hirshdale dump	--	392209	1200333	USGS	P	1980	1	B
135	10344993	Truckee River below Hirshdale dump	--	392209	1200330	USGS	P	1980	1	B
136	--	Truckee River at Gray C	--	392220	1200150	CWRCB	P	1980	1	F
137	10345909	Truckee River at Floriston Dam	--	392348	1200124	USGS	P	1980	1	B
138	10346000	Truckee River at Farad	932	392541	1200159	USGS	P	1974-78	17	W
	392513120015102					USGS	N	1970-82	165	W
	--					USFWS	P	1978-84	10	F
	392513120015102					USEPA	P	1979	1	WBF
	392517120015401					NDEP	N	1970-90	236	W
139	392710120001501	Truckee River at Steamboat ditch	--	392710	1200015	USEPA	P	1981-85	2	W
140	--	Truckee Trailer Park	--	393000	1195900 ^a	NBCHP	P	1985	1	W
141	10347320	Truckee River at Bridge Street, Verdi	--	393127	1195932	USGS	P	1980	1	B
142	10347335	Truckee River below Viking Plant	--	393118	1195825	USGS	P	1980	1	B
143	393027119540901	Truckee River at Circle C Ranch	--	393027	1195409	NDEP	N	1970-90	186	W
144	10347690	Truckee River at Mayberry Drive	--	393024	1195317	USGS	P	1980	1	B
145	393117119494401	Truckee River at Idlewild Park	--	393117	1194944	NDEP	N	1970-90	240	W
146	10347861	Truckee River in Wingfield Park	--	393127	1194858	USGS	P	1980	1	B
147	393142119463501	Truckee River at Glendale Street	--	393142	1194635	USEPA	P	1987	1	W

Appendix A. Selected surface-water sites with available pesticide (water years 1966-92), nutrient (water year 1970 through April 1990), or suspended-sediment (water year 1970 through April 1990) analyses for the Las Vegas Valley area and the Carson and Truckee River Basins—Continued

Site number (pls. 1 and 2)	Site identification	Site name	Drainage area, (square miles)	Location		Agency	Con- sti- tuent	Period of record	Number of samples	Matrix sampled
				Lati- tude	Longi- tude					
Truckee River Basin—Continued										
148	--	Stormwater Drain above East McCarran	--	393103	1194426	NDEP	P	1987	1	W
149	10348200	Truckee River near Sparks	1,070	393111	1194427	USGS	P	1980	1	B
	393103119442604					USGS	N	1979-80	36	W
	393103119442601					NDEP	N	1985-90	160	W
	393103119442601					NDEP	P	1987	1	W
						NDEP	N	1970-90	275	W
150	10348300	North Truckee Drain at Kleppe Lane	--	393130	1194218	USGS	P	0	1	B
	10348300					USGS	N	1979-80	37	W
	393130119421701					NDEP	N	1985-90	37	W
151	393118119421701	North Truckee Drain at Truckee River	--	393118	1194217	USEPA	P	1981-82	2	W
152	--	Hobart Creek Reservoir	--	391100	1195200 ^a	NBCHP	P	1978-89	6	W
153	10348700	Washoe Lake near Carson City	82.8	391448	1194722	USGS	P	1986	1	WB
154	--	Boynnton Slough above Steamboat Creek	--	392939	1194328	USEPA	P	1987	1	W
155	10349980	Steamboat Creek at Kimlick Lane	--	393047	1194241	USGS	P	1980	1	B
	10349980					USGS	N	1979-80	43	W
	393047119424001					NDEP	N	1970-90	420	W
156	10350000	Truckee River at Vista	1,431	393105	1194058	USGS	P	1980	1	B
157	393048119370801	Truckee River below Vista gage	--	393052	1194041	NDEP	N	1973-90	278	W
158	10350050	Truckee River at Lockwood	1,433	393036	1193852	USGS	P	1974-80	20	W
	10350050					USGS	N	1974-85	179	W
	393036119385201					USEPA	P	1979	1	WBF
	393030119410602					NDEP	N	1985-90	187	W
159	10350200	Truckee River at Patrick	--	393249	1193459	USGS	N	1979-84	39	W
160	10350500	Truckee River at Clark	1,600	393356	1192908	USGS	N	1979-80	17	W
	393359119285002					NDEP	N	1985-90	165	W
	393359119285001					NDEP	N	1970-90	321	W
161	10351000	Truckee River at Derby Dam	--	393508	1192654	USGS	P	1980	1	B
						USGS	N	1979-80	37	W
						NDEP	N	1985-90	58	W

Appendix A. Selected surface-water sites with available pesticide (water years 1966-92), nutrient (water year 1970 through April 1990), or suspended-sediment (water year 1970 through April 1990) analyses for the Las Vegas Valley area and the Carson and Truckee River Basins—Continued

Site number (pls. 1 and 2)	Site identification	Site name	Drainage area, (square miles)	Location		Agency	Con- sti- tuent	Period of record	Number of samples	Matrix sampled
				Latitude	Longitude					
Truckee River Basin—Continued										
162	393508119262601	Truckee River below Derby Dam	--	393508	1192626	USEPA	N	1972-73	6	W
163	10351619	Truckee River at Painted Rock	--	393528	1192159	USGS	N	1980	14	W
164 ²	10351322	Fernley Check Dam near Fernley	--	393529	1191442	USGS	P	1980	1	B
165 ^b	393708119073801	South Pond at east outlet	--	393708	1190738	USGS	P	1987-88	2	B
166 ^b	393730119064101	Northeast Pond at outlet	--	393730	1190641	USGS	P	1987-88	2	B
167	10351648	Truckee River at U.S. Highway 40, Wadsworth	--	393755	1191654	USGS	P	1980	1	B
168	393624119200601	Truckee River near Fernley	--	393819	1191651	USFWS	P	1970-84	8	F
	393723119170101					USEPA	P	1980	1	WBF
169	10351650	Truckee River at Wadsworth	1,728	393823	1191654	USGS	N	1979-80	42	W
	393823119165402					NDEP	N	1985-90	98	W
	393823119165401					NDEP	N	1970-90	239	W
170	10351690	Truckee River at Dead Ox Wash	--	394414	1191924	USGS	N	1979-80	21	W
171	10351700	Truckee River near Nixon	1,827	394640	1192010	USGS	P	1975-83	14	B
						USGS	N	1973-90	136	W
						USGS	S	1970-90	193	W
172	10351725	Truckee River at Numana Dam	--	394723	1192054	USGS	P	1980	1	B
173	10351750	Truckee River at Highway 447, Nixon	--	394945	1192136	USGS	N	1979-80	33	W
	394945119213601					NDEP	N	1969-90	225	W
	394945119213602					NDEP	N	1985-90	191	W
174	10351775	Truckee River at Marble Bluff Dam	2,730	395120	1192332	USGS	N	1979-80	33	W
						NDEP	N	1985-90	53	W
175	10351793	Truckee River Delta at Pyramid Lake	--	395053	1192647	USGS	P	1980	1	B
176	395710119354001	Pyramid Lake	--	395710	1193540	USEPA	P	1981	1	WB

¹ Latitude and longitude accurate only to the minutes.

² These sites are in a the Fernley Hydrographic Area, which is traversed by the Truckee Canal.

Appendix B. Selected ground-water sites with available nutrient and pesticide analyses for the Las Vegas Valley area and the Carson and Truckee River Basins, water year 1970 through April 1990

Constituent: N, nutrients; P, pesticides.

Agency: CDHS, California Department of Health Services Branch of Sanitary Engineers; CDPR, California Department of Pesticide Regulation Branch of Environmental Hazards; IVGID, Incline Village General Improvement District; NBCHP, Nevada Bureau of Consumer Health Protection Services; NDEP, Nevada Division of Environmental Protection; USEPA, U.S. Environmental Protection Agency STORET data base; USGS, U.S. Geological Survey.

Symbol: --, not available

Site number (pls. 1 and 2)	Site identification	Site name ¹	Location		Constituent	Agency
			Latitude	Longitude		
Las Vegas Valley area						
1	363332115244001	212 S16 E58	363328	1152438	N	USGS
2	363212115240301	212 S16 E58 24BB1	363212	1152403	N	USGS
3	362006115391801	212 S18 E56 35DCAB1	362006	1153918	N	USGS
4	361939115154801	212 S19 E60 04DAB1	361939	1151548	N	USGS
5	361911115165000	--	361911	1151650	N	USGS
6	361840115153901	212 S19 E60 09DAD1	361840	1151539	N	USGS
7	361833115372501	--	361833	1153725	P	USGS
8	361826115402801	212 S19 E56 10DDBC1	361826	1154028	N	USGS
9	361811115404401	212 S19 E56 15ABAD1	361811	1154044	N	USGS
10	361804115292501	Grapevine Spring	361804	1152925	N	USGS
11	361740115395501	--	361740	1153955	P	USGS
12	361738115410001	--	361738	1154100	P	USGS
13	361612115353301	Daines	361612	1153533	N	USGS
14	361607115353801	212 S19 E57 28CACA1	361607	1153538	N	USGS
15	361607115161800	212 S19 E60 28CA	361607	1151618	P	NBCHP
16	361606115161700	212 S19 E60 28CA	361606	1151617	P	NBCHP
17	361555115392902	Echo Spring	361554	1153923	N	USGS
18	361555115392901	212 S19 E56 26DBDD1	361555	1153929	N	USGS
19	361542115042901	212 S19 E62 32BBAA1	361542	1150429	N	USGS
20	361536115131301	212 S19 E60 25CCC1	361536	1151313	N	USGS
21	361534115374701	212 S19 E57 31BA1	361534	1153742	N	USGS
22	361524115384501	212 S19 E56 36BABD1	361524	1153845	N	USGS
23	361513115392301	--	361513	1153923	P	USGS
24	361445115001601	212 S19 E62 36CCB1	361445	1150016	N	USGS
25	361442115144000	--	361442	1151440	N	USGS
26	361433115144000	--	361433	1151440	N	USGS
27	361425115061501	212 S20 E61 01ACCD1	361425	1150615	N	USGS
28	361421115001601	212 S20 E62 01BBC1	361421	1150016	N	USGS
29	361418115081201	212 S20 E61 03DAD1	361418	1150812	N	USGS
30	361417115161301	212 S20 E60 04CAD1	361417	1151613	N	USGS
31	361410115031101	212 S20 E62 04BDC1	361410	1150311	N	USGS
32	361400115020000	212 S20 E62 04	361400	1150200	P	NBCHP
33	361350115130800	--	361350	1151308	N	USGS
34	361339115130500	--	361339	1151305	N	USGS
35	361329115062301	212 S20 E61 12DBC1	361329	1150623	N	USGS

Appendix B. Selected ground-water sites with available nutrient and pesticide analyses for the Las Vegas Valley area and the Carson and Truckee River Basins, water year 1970 through April 1990—Continued

Site number (pls. 1 and 2)	Site identification	Site name ¹	Location		Constituent	Agency
			Latitude	Longitude		
Las Vegas Valley area—Continued						
36	361305115073201	212 S20 E61 11CDDC1	361305	1150732	N	USGS
37	361303115140301	212 S20 E60 11CAAA1	361303	1151403	N	USGS
38	361238115112102	212 S20 E61 18ABB2	361238	1151121	N	USGS
39	361237115120600	--	361237	1151206	N	USGS
40	361233115021501	212 S20 E62 15BBAB1	361233	1150215	N	USGS
41	361231115132400	--	361231	1151324	N	USGS
42	361227115125500	--	361227	1151255	N	USGS
43	361212115154201	212 S20 E60 21AAB1	361212	1151542	N	USGS
44	361212115065901	212 S20 E61 14CCCC1	361212	1150659	N	USGS
45	361204115024901	212 S20 E62 21AAC1	361204	1150249	N	USGS
46	361200115140000	212 S20 E60 14	361200	1151400	P	NBCHP
47	361140115121401	212 S20 E61 19BCC1	361140	1151214	N	USGS
48	361136115140000	212 S20 E60 23CAD	361136	1151400	P	NBCHP
49	361117115114101	212 S20 E61 30ABB1	361117	1151141	N	USGS
50	361110115082401	212 S20 E61 22DCD1	361110	1150824	N	USGS
51	361102115083601	212 S20 E61 27BDAA1	361102	1150836	N	USGS
52	361053115120501	212 S20 E61 30BDC1	361053	1151158	N	USGS
53	361027115284301	212 S20 E58 1	361027	1152843	N	USGS
54	361026115111401	212 S20 E61 30DC1	361026	1151114	N	USGS
55	361013115112900	212 S20 E61 31AAC	361013	1151129	P	NBCHP
56	361010115174000	212 S20 E60 32BCB	361010	1151740	P	NBCHP
57	360940115133701	212 S20 E60 35DDA2	360940	1151337	N	USGS
58	360937115113401	212 S20 E61 31DCD1	360937	1151134	N	USGS
59	360933115055102	212 S20 E61 36DDD2	360933	1150551	N	USGS
60	360933115055101	212 S20 E61 36DDD1	360933	1150551	N	USGS
61	360924115081101	212 S21 E61 03AAAD1	360924	1150811	N	USGS
62	360921115093601	212 S21 E61 04ABC1	360921	1150936	N	USGS
63	360908115062901	212 S21 E61 01ACCC1	360908	1150629	N	USGS
64	360838115101801	212 S21 E61 09BBBB1	360838	1151018	N	USGS
65	360832115060201	212 S21 E63 30AAAA1	360559	1145827	N	USGS
66	360817115085701	212 S21 E61 10BCAD1	360817	1150857	N	USGS
67	360749115050801	212 S21 E62 17AAB1	360749	1150508	N	USGS
68	360744115260301	212 S21 E58 1	360744	1152603	N	USGS
69	360735115105201	212 S21 E61 17BADD1	360735	1151052	N	USGS
70	360728115072901	212 S21 E61 14ACA1	360728	1150729	N	USGS
71	360719115095901	212 S21 E61 16CA1	360719	1150959	N	USGS
72	360701115081301	212 S21 E61 15DDDD1	360701	1150813	N	USGS
73	360632115015501	212 S21 E62 22ADCB1	360631	1150153	N	USGS
74	360631115011801	212 S21 E62 23BDD1	360631	1150117	N	USGS
75	360631115005301	212 S21 E62 23ADCB1	360631	1150052	N	USGS

Appendix B. Selected ground-water sites with available nutrient and pesticide analyses for the Las Vegas Valley area and the Carson and Truckee River Basins, water year 1970 through April 1990—Continued

Site number (pls. 1 and 2)	Site identification	Site name ¹	Location		Consti- tuent	Agency
			Latitude	Longitude		
Las Vegas Valley area—Continued						
76	360625115070701	212 S21 E61 23DAB1	360625	1150707	N	USGS
77	360622115013002	212 S21 E62 23CBAC2	360621	1150129	N	USGS
78	360621115020701	212 S21 E62 22DBBD1	360621	1150205	N	USGS
79	360621115010501	212 S21 E62 23DBBD1	360621	1150104	N	USGS
80	360617115063801	212 S21 E61 24CAD1	360617	1150638	N	USGS
81	360612115005801	212 S21 E62 23DCAA1	360612	1150058	N	USGS
82	360606115010501	212 S21 E62 23DCCA1	360606	1150106	N	USGS
83	360605115154601	212 S21 E60 21DD1	360605	1151546	N	USGS
84	360602115015501	212 S21 E62 22DDCD1	360601	1150153	N	USGS
85	360602115012901	212 S21 E62 23CCDD1	360601	1150129	N	USGS
86	360602115011703	212 S21 E62 23CDDC3	360602	1150117	N	USGS
87	360602115011701	212 S21 E62 23CDDC1	360601	1150117	N	USGS
88	360601115005301	212 S21 E62 23DDCC1	360601	1150052	N	USGS
89	360548115024601	212 S21 E62 28AAC1	360548	1150246	N	USGS
90	360542115065001	212 S21 E61 25BDA1	360542	1150650	N	USGS
91	360537114570501	212 S21 E63 28AC2	360537	1145705	N	USGS
92	360529115010001	212 S21 E62 26DBA2	360529	1150100	N	USGS
93	360522114582401	212 S21 E63 29CCBA1	360522	1145824	N	USGS
94	360520114583801	212 S21 E63 29CC1	360520	1145838	N	USGS
95	360506115001101	212 S21 E62 36BABD1	360503	1150014	P	USGS
96	360459114592201	212 S21 E63 31BBAA2	360507	1145922	P	USGS
97	360459114584901	212 S21 E63 31ABDA1	360459	1145849	N	USGS
98	360457114593501	212 S21 E62 36AADD1	360457	1145935	N	USGS
99	360451114593501	212 S21 E63 31BCBC1	360451	1145935	N	USGS
100	360444115132301	212 S21 E60 35ADAB1	360444	1151323	N	USGS
101	360434114594800	Pittman underdrain	360434	1145948	P	USEPA
102	360433114591701	212 S21 E63 31CBDA1	360433	1145917	N	USGS
103	360426114590001	212 S21 E63 31DCBB1	360426	1145900	N	USGS
104	360418114592501	212 S21 E63 31CCDC1	360418	1145925	P	USGS
105	360416115000601	212 S21 E62 36DCCC1	360416	1150006	N	USGS
106	360416114592901	212 S22 E63 06BBBA1	360416	1145929	N	USGS
107	360415115064101	212 S22 E61 01BAB1	360415	1150641	N	USGS
108	360414115002201	212 S22 E62 01BABB1	360414	1150022	P	USGS
109	360414115001301	212 S22 E62 01BAAB1	360414	1150013	P	USGS
110	360414115000501	212 S22 E62 01ABBC1	360414	1150005	P	USGS
111	360414115000101	212 S22 E62 01ABBA2	360414	1150001	P	USGS
112	360414114595701	212 S22 E62 01ABAB2	360414	1145957	P	USGS
113	360414114595301	212 S22 E62 01ABAA1	360414	1145953	N, P	USGS
114	360414114593501	212 S22 E62 01AAAA1	360414	1145935	P	USGS
115	360407115075602	212 S22 E61 02BBD2	360407	1150556	N	USGS

Appendix B. Selected ground-water sites with available nutrient and pesticide analyses for the Las Vegas Valley area and the Carson and Truckee River Basins, water year 1970 through April 1990—Continued

Site number (pls. 1 and 2)	Site identification	Site name ¹	Location		Consti- tuent	Agency
			Latitude	Longitude		
Las Vegas Valley area—Continued						
116	360403114595401	212 S22 E62 01ACAA1	360403	1145954	P	USGS
117	360354114593801	212 S22 E62 01ADDD1	360354	1145938	P	USGS
118	360353115004300	212 S21 E62 35	360353	1150043	P	USEPA
119	360349115064901	212 S22 E61 01CBA1	360349	1150649	N	USGS
120	360348115000901	212 S22 E62 01CAAA1	360348	1150009	P	USGS
121	360347115280901	212 S22 E58 03CBA1	360347	1152809	N	USGS
122	360344114584301	212 S22 E63 06DABD1	360344	1145843	P	USGS
123	360344114582501	212 S22 E62 05CBBB1	360348	1145831	P	USGS
124	360340114595900	212 S22 E62 01	360340	1145959	P	USEPA
125	360340114595301	212 S22 E62 01DBDA1	360340	1145953	P	USGS
126	360335115002301	212 S22 E62 01BCDD1	360335	1150023	P	USGS
127	360330114594800	212 S22 E62 01	360330	1145948	P	USEPA
128	360322115030801	212 S22 E62 04DCCC1	360322	1150308	N	USGS
129	360322115001901	212 S22 E62 01CDCC1	360322	1150019	P	USGS
130	360319114594001	212 S22 E62 12AAAC1	360319	1145940	P	USGS
131	360307115112301	212 S22 E61 07BCB1	360307	1151123	N	USGS
132	360303114593601	212 S22 E62 12ADAD1	360303	1145936	N	USGS
133	360302114594001	212 S22 E62 12ADDB1	360302	1145940	P	USGS
134	360102115100901	212 S22 E61 21CD1	360102	1151009	N	USGS
135	360042115150501	212 S22 E60 27ABB1	360042	1151505	N	USGS
Carson River Basin						
136	393930118445201	101 N19 E29 08DABC1	393141	1184511	N	USGS
137	393714118490701	101 N20 E28 10AAA1	393714	1184907	N	USGS
138	393651118325701	101 N20 E31 07BDCA1	393651	1183257	N	USGS
139	393621118490701	101 N20 E28 14BBB1	393621	1184907	N	USGS
140	393531118482301	101 N20 E28 14DCC1	393531	1184823	N	USGS
141	393515118495601	101 N20 E28 22BCA1	393515	1184956	N	USGS
142	393506118473001	101 N20 E28 24BDD1	393506	1184730	N	USGS
143	393505118503601	101 N20 E28 21ACD1	393505	1185036	N	USGS
144	393459118330602	101 N20 E31 19CBD2	393459	1183306	N	USGS
145	393458118482700	101 N20 E28 23DB1	393458	1184827	P	NDEP
146	393458118431101	101 N20 E29 22CBAC1	393506	1184322	P	USGS
147	393458118431101	101 N20 E29 22CBAC1	393506	1184322	N	USGS
148	393417118512001	101 N20 E28 28BCC1	393417	1185120	N	USGS
149	393356118495501	101 N20 E28 27CCA1	393356	1184955	N	USGS
150	393354118503401	101 N20 E28 28DCA1	393354	1185034	N	USGS
151	393346118510301	101 N20 E28 28CDC1	393346	1185103	N	USGS
152	393342118514101	101 N20 E28 32AAB1	393342	1185136	N	USGS
153	393341118431601	101 N20 E29 34BBAC1	393341	1184316	N	USGS
154	393327118304101	101 N20 E31 33BDCA1	393327	1183041	N	USGS
155	393320118501401	101 N20 E28 33ADDD1	393320	1185014	N	USGS

Appendix B. Selected ground-water sites with available nutrient and pesticide analyses for the Las Vegas Valley area and the Carson and Truckee River Basins, water year 1970 through April 1990—Continued

Site number (pls. 1 and 2)	Site identification	Site name ¹	Location		Consti- tuent	Agency
			Latitude	Longitude		
Carson River Basin—Continued						
156	393310118515501	101 N20 E28 32CAD1	393310	1185155	N	USGS
157	393252118431401	101 N20 E29 34CCDC1	393252	1184314	N	USGS
158	393251118512103	101 N20 E28 32DDD3	393251	1185121	N	USGS
159	393242118534001	101 N19 E27 01AAD1	393246	1185340	N	USGS
160	393236118331601	101 N19 E31 06BCBB1	393236	1183316	N	USGS
161	393129118454601	101 N19 E29 07DAAD1	393129	1184546	N	USGS
162	393112118361300	101 N19 E30 10CDD1	393112	1183613	N	USGS
163	393101118451801	101 N19 E29 17BABD1	393101	1184518	N	USGS
164	393052118333501	101 N19 E30 13ACAA1	393052	1183335	N, P	USGS
165	393038118512201	101 N19 E28 17DAAC1	393038	1185122	N, P	USGS
166	393027118461501	101 N19 E29 18DCBB1	393027	1184615	N	USGS
167	393018118544001	101 N19 E27 13CCCB1	393018	1185440	N	USGS
168	393014118384101	101 N19 E29 08BBBB1	393014	1183841	N	USGS
169	393005118314701	101 N19 E31 20BBD1	393008	1183159	N	USGS
170	393004118511301	101 N19 E28 21BBCA1	393004	1185113	N	USGS
171	393003118402001	101 N19 E29 24ABDD1	393003	1184020	N, P	USGS
172	393001118565901	101 N19 E27 21ACAA1	393001	1185659	N	USGS
173	392957119001801	101 N19 E27 19BCB1	392957	1190018	N	USGS
174	392950118470401	101 N19 E28 24ADCC1	392950	1184704	N	USGS
175	392947118470301	101 N19 E28 24DABB1	392947	1184703	N	USGS
176	392941118321401	101 N19 E31 19DADB1	392941	1183214	N	USGS
177	392938118345301	101 N19 E30 23DBCD1	392938	1183453	N	USGS
178	392929118490701	101 N19 E28 22DDAD1	392929	1184907	N	USGS
179	392926118533001	101 N19 E28 19CCCB1	392926	1185330	N, P	USGS
180	392925118482001	101 N19 E28 23DCDB1	392925	1184820	N	USGS
181	392921118400001	101 N19 E30 30BBBA1	392921	1184000	N	USGS
182	392914118400601	101 N19 E29 25AADA1	392914	1184006	N	USGS
183	392907118453701	101 N19 E29 29BACB1	392907	1184537	N	USGS
184	392904118401301	101 N19 E29 25ADBD1	392904	1184013	N	USGS
185	392903118524401	101 N19 E28 30ADBC1	392903	1185244	N	USGS
186	392902118353201	101 N19 E30 27ADDA1	392902	1183532	N, P	USGS
187	392859118474001	101 N19 E28 25BCDD1	392859	1184740	N	USGS
188	392857118335901	101 N19 E30 25ABB1	392857	1183348	N	USGS
189	392850118485500	101 N19 E28 26CB1	392850	1184855	P	NDEP
190	392850118463401	101 N19 E29 30CBAD1	392850	1184634	N	USGS
191	392847118451801	101 N19 E29 29CACA1	392847	1184518	N	USGS
192	392842118425401	101 N19 E29 27CDAA1	392842	1184254	N, P	USGS
193	392837118463201	101 N19 E29 30CDBC1	392837	1184632	N	USGS
194	392837118462901	101 N19 E29 30CDBC2	392837	1184629	N	USGS
195	392835118490501	101 N19 E28 27DDDA1	392835	1184905	N	USGS

Appendix B. Selected ground-water sites with available nutrient and pesticide analyses for the Las Vegas Valley area and the Carson and Truckee River Basins, water year 1970 through April 1990—Continued

Site number (pls. 1 and 2)	Site identification	Site name ¹	Location		Consti- tuent	Agency
			Latitude	Longitude		
Carson River Basin—Continued						
196	392829118520001	101 N19 E28 32BAAB1	392829	1185200	N, P	USGS
197	392828118361201	101 N19 E30 34BAA1	392828	1183612	N	USGS
198	392825118470501	101 N19 E28 36AABC1	392825	1184705	N	USGS
199	392825118395001	101 N19 E30 31BBAD1	392822	1183954	N, P	USGS
200	392817118495501	101 N19 E28 34BCAA1	392813	1184953	N, P	USGS
201	392802118443201	101 N19 E29 33CBBB2	392802	1184432	N	USGS
202	392800118443201	101 N19 E29 33CBBC1	392800	1184432	N	USGS
203	392758118365102	101 N19 E30 33ABD1	392758	1183651	N	USGS
204	392748118515701	101 N19 E28 32CDAB1	392748	1185157	N, P	USGS
205	392733118463801	101 N18 E29 06BBBD5	392733	1184638	N	USGS
206	392730118464000	101 N18 E29 06BB1	392730	1184640	P	NDEP
207	392730118414801	101 N18 E29 02BADA1	392730	1184148	N	USGS
208	392659118444001	101 N18 E29 05DDAB1	392659	1184440	N	USGS
209	392648118454001	101 N18 E29 05CCCB1	392648	1184540	N	USGS
210	392642118470901	101 N18 E28 12ABAC1	392642	1184709	N, P	USGS
211	392621118522301	101 N18 E28 08BCCC1	392621	1185223	N	USGS
212	392615118494301	101 N18 E28 10CAAA1	392615	1184943	N	USGS
213	392548118461801	101 N18 E29 18BAAD1	392548	1184618	N	USGS
214	392518119170401	102 N18 E24 15CCBA1	392518	1191704	N	USGS
215	392515119123701	102 N18 E25 17CCBC1	392515	1191237	N	USGS
216	392458118444801	101 N18 E29 20AABC1	392458	1184448	N, P	USGS
217	392442118380101	101 N18 E28 23ADAA1	392431	1184659	N	USGS
218	392439118480401	101 N18 E28 23ADDB1	392425	1184704	N, P	USGS
219	392403119135101	102 N18 E24 25AADC1	392403	1191351	N	USGS
220	392351118462601	101 N18 E29 30BDBA1	392351	1184626	N	USGS
221	392349119114301	102 N18 E25 29ADCD1	392349	1191143	N	USGS
222	392330119175401	102 N18 E24 28CDBD1	392330	1191754	N	USGS
223	392327118425401	101 N18 E29 27CDAD1	392327	1184254	N, P	USGS
224	392325118433101	101 N18 E29 28DDCD1	392319	1184338	N	USGS
225	392320119150901	102 N18 E24 35ABAD1	392320	1191509	N	USGS
226	392311119174501	102 N18 E24 33BDAA1	392311	1191745	N	USGS
227	392235119215601	103 N18 E23 35DCDC1	392235	1192156	N	USGS
228	392232118485101	101 N18 E28 35CDBD1	392232	1184851	N	USGS
229	392226119162101	102 N17 E24 03ABAD1	392226	1191621	N	USGS
230	392222118462102	101 N17 E29 06BAA1	392222	1184621	N	USGS
231	392207118463601	101 N17 E29 06BCAD1	392207	1184636	N	USGS
232	392201119245001	103 N17 E23 04CBBB2	392201	1192450	N	USGS
233	392200119220000	103 N18 E23 35	392200	1192200	P	NBCHP
234	392200118454201	101 N17 E29 05BCBB1	392200	1184542	N	USGS
235	392144119223401	103 N17 E23 02BC1	392144	1192234	N	USGS

Appendix B. Selected ground-water sites with available nutrient and pesticide analyses for the Las Vegas Valley area and the Carson and Truckee River Basins, water year 1970 through April 1990—Continued

Site number (pls. 1 and 2)	Site identification	Site name ¹	Location		Consti- tuent	Agency
			Latitude	Longitude		
Carson River Basin—Continued						
236	392132118411002	101 N17 E29 12BBBB2	392132	1184110	N	USGS
237	392115119233901	103 N17 E23 10BCCA1	392118	1192349	N	USGS
238	392018118444302	101 N17 E29 17ADDB2	392018	1184443	N	USGS
239	392007119253501	103 N17 E23 17DCBC1	392007	1192535	N	USGS
240	391941119125101	102 N17 E25 18DDD1	391952	1191240	N	USGS
241	391936119315101	103 N17 E22 20DABB1	391936	1193151	N	USGS
242	391847119113801	102 N17 E25 29ADAB1	391847	1191138	N, P	USGS
243	391837119330501	103 N17 E22 30DABC1	391837	1193305	N	USGS
244	391823119293401	103 N17 E22 27DACC1	391823	1192934	N	USGS
245	391808119120701	102 N17 E25 32BAAA1	391808	1191207	N, P	USGS
246	391748119211501	103 N17 E23 36BADC1	391758	1192110	N	USGS
247	391728119160601	102 N17 E24 34DDAC1	391728	1191606	N	USGS
248	391723119315001	103 N17 E22 32DDBC1	391723	1193150	N	USGS
249	391627119332101	103 N16 E22 06CDD1	391627	1193321	N	USGS
250	391610119335901	103 N16 E21 12ADAB1	391610	1193359	N, P	USGS
251	391605119313401	103 N16 E22 09BCBC1	391605	1193134	N, P	USGS
252	391538119383501	103 N16 E21 08DDCB1	391538	1193835	N	USGS
253	391538119311301	103 N16 E22 09CACA1	391538	1193113	N	USGS
254	391519119351701	103 N16 E21 14ADBA1	391519	1193517	N	USGS
255	391441119370101	103 N16 E21 15CCDC1	391441	1193701	N	USGS
256	391417119351801	103 N16 E21 23ACDD1	391417	1193518	N	USGS
257	391308119355201	103 N16 E21 26BCB1	391330	1193552	N	USGS
258	391259119384201	103 N16 E21 29DCDD1	391259	1193842	N	USGS
259	391251119491701	104 N15 E20 21CABA1	390857	1194434	N	USGS
260	391234119464001	104 N16 E20 31ACCB1	391234	1194640	N	USGS
261	391224119472101	104 N16 E19 36DAAC1	391210	1194653	N	USGS
262	391204119451401	104 N15 E20 05ABDA1	391204	1194514	N	USGS
263	391201119481801	104 N15 E19 02AAAA1	391201	1194818	N	USGS
264	391133119461701	104 N15 E20 06DAAC2	391133	1194617	N	USGS
265	391130119450501	104 N15 E20 16AD1	391130	1194505	N	USGS
266	391128119415701	104 N15 E20 01CCBC1	391108	1194207	N	USGS
267	391123119435301	104 N15 E20 03CCCB1	391123	1194353	N	USGS
268	391121119422801	104 N15 E20 02CDCC1	391121	1194228	N	USGS
269	391120119461701	104 N15 E20 06DDAC1	391120	1194617	N, P	USGS
270	391113119481901	104 N15 E19 02DDDC1	391113	1194819	N	USGS
271	391104119454801	104 N15 E20 08BDBB1	391104	1194548	N	USGS
272	391058119424602	104 N15 E20 10ADDA2	391058	1194246	N	USGS
273	391053119432501	104 N15 E20 10BDDA1	391053	1194325	N, P	USGS
274	391039119445701	104 N15 E20 09CAD1	391039	1194457	N	USGS
275	391039119443001	104 N15 E20 09DBD1	391039	1194430	N, P	USGS

Appendix B. Selected ground-water sites with available nutrient and pesticide analyses for the Las Vegas Valley area and the Carson and Truckee River Basins, water year 1970 through April 1990—Continued

Site number (pls. 1 and 2)	Site identification	Site name ¹	Location		Consti- tuent	Agency
			Latitude	Longitude		
Carson River Basin—Continued						
276	391037119461501	104 N15 E20 07DAAC1	391037	1194615	N, P	USGS
277	391036119470001	104 N15 E20 07CACB1	391036	1194700	N	USGS
278	391036119440701	104 N15 E20 09DACC1	391039	1194402	N	USGS
279	391035119471501	104 N15 E19 12DADD2	391035	1194715	N	USGS
280	391035119454201	104 N15 E20 08CADC1	391035	1194542	N, P	USGS
281	391031119462301	104 N15 E20 07DDBB1	391031	1194623	N	USGS
282	391017119475501	104 N15 E19 12CDBD1	391017	1194755	N	USGS
283	391014119450701	104 N15 E20 17AADC1	391014	1194507	N	USGS
284	391013119455001	104 N15 E20 17BACC1	391013	1194550	N, P	USGS
285	391010119452101	104 N15 E20 17ABD1	391010	1194521	N, P	USGS
286	391008119450602	104 N15 E20 17AADC5	391008	1194506	N	USGS
287	391008119450601	104 N15 E20 17AADC4	391008	1194506	N	USGS
288	391007119465301	104 N15 E20 08BAC1	391007	1194653	N, P	USGS
289	391005119465701	104 N15 E20 18ACAA1	391005	1194657	N	USGS
290	391005119450001	104 N15 E20 16BBBB1	391005	1194500	N, P	USGS
291	390957119454804	104 N15 E20 17CABA4	390957	1194548	P	USGS
292	390957119454803	104 N15 E20 17CABA3	390957	1194548	N, P	USGS
293	390957119454802	104 N15 E20 17CABA2	390957	1194548	P	USGS
294	390957119454801	104 N15 E20 17CABA1	390957	1194548	P	USGS
295	390950119452901	104 N15 E20 17DBBD1	390950	1194529	N	USGS
296	390949119421501	103 N15 E20 14CAAA1	390955	1194215	N	USGS
297	390945119462801	104 N15 E20 18DCA1	390945	1194628	N, P	USGS
298	390943119453801	104 N15 E20 17CAD1	390943	1194538	N, P	USGS
299	390943119450004	104 N15 E20 16BCBC4	390943	1194500	P	USGS
300	390943119450003	104 N15 E20 16BCBC3	390943	1194500	N, P	USGS
301	390943119450002	104 N15 E20 16BCBC2	390943	1194500	P	USGS
302	390943119450001	104 N15 E20 16BCBC1	390943	1194500	P	USGS
303	390938119480001	104 N15 E19 13CDBB1	390938	1194800	N	USGS
304	390933119450601	104 N15 E20 17DDDA1	390933	1194506	N	USGS
305	390925119452001	104 N15 E20 20ABAA1	390925	1194520	N, P	USGS
306	390917119430701	103 N15 E20 22ABCA1	390917	1194307	N, P	USGS
307	390915119455501	104 N15 E20 20BBDD1	390915	1194555	N, P	USGS
308	390915119444601	104 N15 E20 21BACC1	390915	1194446	N, P	USGS
309	390914119420002	103 N15 E20 23ABDD2	390914	1194200	N	USGS
310	390857119450201	104 N15 E20 21CBBC1	390857	1194502	N, P	USGS
311	390855119452901	104 N15 E20 20DBBD1	390855	1194529	N, P	USGS
312	390852119454601	104 N15 E20 20CACC1	390852	1194546	N	USGS
313	390840119422501	103 N15 E20 23CDAC1	390840	1194210	N	USGS
314	390833119480001	105 N15 E20 33CCDD1	390653	1194443	N	USGS
315	390809119454401	104 N15 E20 29BCAC1	390803	1194542	N	USGS

Appendix B. Selected ground-water sites with available nutrient and pesticide analyses for the Las Vegas Valley area and the Carson and Truckee River Basins, water year 1970 through April 1990—Continued

Site number (pls. 1 and 2)	Site identification	Site name ¹	Location		Consti- tuent	Agency
			Latitude	Longitude		
Carson River Basin—Continued						
316	390802119461701	104N15 E20 29BBDB1	390802	1194617	N	USGS
317	390743119463101	104 N15 E20 31BABA1	390743	1194631	N	USGS
318	390732119455601	104 N15 E20 32BBDA1	390733	1194555	N	USGS
319	390655119463101	104 N15 E20 31DCC1	390655	1194631	N	USGS
320	390652119455401	104 N14 E20 05BBAB1	390642	1194554	N	USGS
321	390647119500501	104 N15 E19 33DDDD1	390647	1195005	N	USGS
322	390623119470501	104 N14 E20 06CBAB2	390623	1194705	N	USGS
323	390622119470301	104 N14 E20 06CBA1	390622	1194703	N	USGS
324	390612119571901	104 N15 E20 28CCBD1	390751	1194454	N	USGS
325	390558119444301	105 N14 E20 09BAB1	390558	1194443	N	USGS
326	390542119472001	104 N14 E19 12ADAB1	390542	1194720	N	USGS
327	390503119463501	105 N14 E20 18ABAB1	390503	1194635	N, P	USGS
328	390457119491301	105 N14 E19 14BBD1	390457	1194913	N	USGS
329	390446119451401	105 N14 E20 17ADCA1	390446	1194514	N	USGS
330	390422119501401	105 N14 E19	390422	1195014	N	USGS
331	390407119464901	105 N14 E20 19BAD1	390407	1194649	N	USGS
332	390407119451901	105 N14 E20 20AAB1	390407	1194519	N	USGS
333	390343119450501	105 N14 E20 20DAA1	390343	1194505	N	USGS
334	390324119442401	105 N14 E20 21DC1	390324	1194424	N	USGS
335	390318119483001	105 N14 E19 23DD1	390318	1194830	N	USGS
336	390302119465701	105 N14 E20 30BDB1	390302	1194657	N	USGS
337	390259119475301	105 N14 E19 25BDDDB2	390317	1194730	N, P	USGS
338	390237119492101	105 N14 E19 26CCB1	390237	1194921	N	USGS
339	390232119443201	105 N14 E20 28CDC1	390232	1194432	N	USGS
340	390222119462401	105N14 E20 31AAC1	390222	1194624	N	USGS
341	390208119435501	105 N14 E20 34BCC1	390208	1194355	N	USGS
342	390208119433201	105 N14 E20 34BDBD1	390208	1194332	N	USGS
343	390205119464301	105 N14 E20 30DCCB1	390205	1194643	N	USGS
344	390156119492301	105 N14 E19 35CBBC1	390156	1194923	N	USGS
345	390139119461901	105 N14 E20 31DDC1	390139	1194619	N	USGS
346	390137119453601	105 N14 E20 32DCCC1	390137	1194536	N	USGS
347	390110119483001	105 N13 E19 02AD1	390110	1194830	N	USGS
348	390106119424301	105 N13 E20 02CBB1	390106	1194243	N	USGS
349	390048119493401	105 N13 E20 03DDDB1	390048	1194934	N, P	USGS
350	390045119453801	105 N13 E20 05CDD1	390045	1194538	N	USGS
351	390037119480701	105 N13 E19 12BBAD1	390037	1194807	N	USGS
352	390025119412701	105 N13 E20 12BCAD1	390025	1194127	N	USGS
353	390024119453501	105 N13 E20 08ACBC1	390024	1194535	N, P	USGS
354	390021119504301	105 N13 E19 09ADCA1	390021	1195043	N	USGS
355	390017119453901	105 N13 E20 08CAA1	390017	1194539	N	USGS

Appendix B. Selected ground-water sites with available nutrient and pesticide analyses for the Las Vegas Valley area and the Carson and Truckee River Basins, water year 1970 through April 1990—Continued

Site number (pls. 1 and 2)	Site identification	Site name ¹	Location		Consti- tuent	Agency
			Latitude	Longitude		
Carson River Basin—Continued						
356	390015119500101	105 N13 E19 10DBB1	390015	1195001	N	USGS
357	390006119453601	105 N13 E20 08CAD1	390006	1194536	N	USGS
358	390005119461101	105 N13 E20 07DADD1	390005	1194611	N	USGS
359	390000119454101	105 N13 E20 08CDAB1	390000	1194541	N, P	USGS
360	385957119492101	105 N13 E19 11CCDB1	385957	1194921	N	USGS
361	385949119464501	105 N13 E20 18BAAA2	385949	1194645	N	USGS
362	385948119464401	105 N13 E20 18BAAA1	385948	1194644	N	USGS
363	385948119411001	105 N13 E20 31BAAA1	385642	1194645	N	USGS
364	385926119481601	105 N13 E19 13BCC1	385925	1194833	N	USGS
365	385924119454801	105 N13 E20 17BDC1	385924	1194548	N	USGS
366	385853119495501	105 N13 E19 22ABBC1	385853	1194955	N	USGS
367	385859119461501	105 N13 E20 19AAAB1	385859	1194615	N	USGS
368	385842119465601	105 N13 E20 19BACC1	385842	1194656	N, P	USGS
369	385834119464101	105 N13 E20 19ACCC1	385834	1194641	N	USGS
370	385833119470101	105 N13 E20 19CBA1	385833	1194701	N	USGS
371	385822119462501	105 N13 E20 19DABC1	385822	1194625	N, P	USGS
372	385821119475001	105 N13 E19 24CADD1	385821	1194750	N	USGS
373	385820119471301	105 N13 E20 19CCB1	385820	1194713	N	USGS
374	385801119421501	105 N13 E20 26ABBB1	385801	1194215	N	USGS
375	385744119423901	105 N13 E20 26BCAC1	385744	1194239	N	USGS
376	385742119453801	105 N13 E20 29BDDD1	385742	1194538	N	USGS
377	385738119465301	105 N13 E20 30BCAD1	385750	1194657	N	USGS
378	385719119454701	105 N13 E20 29CDC1	385719	1194547	N, P	USGS
379	385708119475501	105N13 E19 25CDD1	385716	1194754	N	USGS
380	385703119381301	105 N13 E21 33BCAB1	385703	1193813	N	USGS
381	385654119431801	105 N13 E20 34ACC1	385654	1194318	N	USGS
382	385652119471401	105 N13 E20 31BCC1	385652	1194714	N	USGS
383	385647119451000	105 N13 E20 32	385647	1194510	P	NBCHP
384	385626119375202	105 N13 E21 33CDDD2	385626	1193752	N	USGS
385	385626119375201	105 N13 E21 33CDDD1	385626	1193752	N	USGS
386	385621119444501	105 N12 E20 04BAB1	385621	1194445	N	USGS
387	385613119455701	105 N12 E20 05BBD1	385613	1194557	N	USGS
388	385604119435601	105 N12 E20 4ADA1	385604	1194356	N, P	USGS
389	385559119485701	105 N12 E19 02BDDD1	385559	1194857	N	USGS
390	385554119461401	105 N12 E20 06ADDD1	385554	1194614	N	USGS
391	385548119501301	105 N12 E19 03CABD1	385548	1195013	N	USGS
392	385546119463701	105 N12 E20 06DB1	385546	1194637	N	USGS
393	385522119481301	105 N12 E19 13BABB1	385522	1194813	N, P	USGS
394	385512119444801	105 N12 E20 09BCAD1	385512	1194448	N	USGS
395	385509119414801	105 N12 E20 11ADD1	385509	1194148	N	USGS

Appendix B. Selected ground-water sites with available nutrient and pesticide analyses for the Las Vegas Valley area and the Carson and Truckee River Basins, water year 1970 through April 1990—Continued

Site number (pls. 1 and 2)	Site identification	Site name ¹	Location		Consti- tuent	Agency
			Latitude	Longitude		
Carson River Basin—Continued						
396	385442119431900	105 N12 E20 10DCC1	385442	1194319	P	NBCHP
397	385441119495501	105 N12 E19 10DCCA1	385441	1194955	N	USGS
398	385439119490901	105 N12 E19 11CDCC1	385439	1194909	N	USGS
399	385436119475301	105 N12 E19 13BAA1	385436	1194753	N	USGS
400	385434119430001	105 N12 E20 15AAB1	385434	1194300	N, P	USGS/ NBCHP
401	385414119425401	105 N12 E20 15ADD1	385414	1194254	N, P	USGS
402	385412119401401	105 N12 E21 18CAB1	385412	1194014	N	USGS
403	385410119494501	105 N12 E19 15DBAA1	385410	1194945	N	USGS
404	385352119455401	105 N12 E20 17CCD1	385352	1194554	N	USGS
405	385345119445101	105 N12 E20 16CCD1	385345	1194451	N	USGS
406	385343119471401	105 N12 E20 19BBB1	385343	1194714	N	USGS
407	385342119451701	105 N12 E20 20ABAA1	385342	1194517	N, P	USGS
408	385321119405002	105 N12 E20 24ADCC2	385321	1194050	N	USGS
409	385312119442700	105 N12 E20 21DBC1	385312	1194427	P	NBCHP
410	385303119480201	105 N12 E19 24CCAA1	385303	1194802	N	USGS
411	385255119482301	105 N12 E19 23DDD1	385255	1194823	N	USGS
412	385205119475301	105 N12 E19 25CDD1	385205	1194753	N	USGS
413	385125119452801	105 N12 E20 32DBBD1	385125	1194528	N, P	USGS
414	385122119471501	105 N12 E19 36DADA2	385122	1194715	N, P	USGS
415	385049119464501	105 N11 E20 06BDA1	385049	1194645	N	USGS
416	384951119462101	105 N11 E20 07ADC1	384951	1194621	N	USGS
417	384616119465501	105 N11 E20 31CABD2	384616	1194655	N, P	USGS
Truckee River Basin						
418	394726119001601	75 N22 E26 12ADB1	394726	1190016	N	USGS
419	393949119084601	76 N21 E25 26BBDA1	393949	1190846	N	USGS
420	393717119153300	76 N20 E24 11	393717	1191533	P	NBCHP
421 ²	393628119112200	76 N20 E25 08DD	393628	1191122	P	NBCHP
422 ²	393627119111900	76 N20 E25 09CC	393627	1191119	P	NBCHP
423 ²	39360011915000A	76 N20 E24 14	393600	1191500	P	NBCHP
424 ²	39360011915000B	76 N20 E24 14	393600	1191500	P	NBCHP
425 ²	393558119095801	76 N20 E25 15CBAA1	393558	1190958	N	USGS
426 ²	393532119144200	76 N20 E25 24BB	393532	1191442	P	NBCHP
427 ²	393526119100401	76 N20 E25 22BBDB1	393523	1191002	N	USGS
428 ²	393459119095601	76 N20 E25 22CBDA1	393459	1190956	N	USGS
429	393200119460000	87 N19 E20 06	393200	1194600	P	NBCHP
430	393200119450000	87 N19 E20 08	393200	1194500	P	NBCHP
431	393100119490000	87 N19 E19 14	393100	1194900	P	NBCHP
432	393100119470000	87 N19 E19 12	393100	1194700	P	NBCHP

Appendix B. Selected ground-water sites with available nutrient and pesticide analyses for the Las Vegas Valley area and the Carson and Truckee River Basins, water year 1970 through April 1990—Continued

Site number (pls. 1 and 2)	Site identification	Site name ¹	Location		Consti- tuent	Agency
			Latitude	Longitude		
Truckee River Basin—Continued						
433	393100119460000	87 N19 E20 18	393100	1194600	P	NBCHP
434	392854119462200	87 N19 E20 30	392854	1194622	P	NBCHP
435	392800119420000	76 N19 E29 31	392800	1194200	P	NBCHP
436	391918120163500	Donner Lake	391918	1201635	N	USGS
437	391552120045101	90 N16 E17 15CCAA1	391355	1200452	N	USGS
438	391533119563000	90 N16 E18 10DDC1	391533	1195630	P	IVGID
439	391524119563100	90 N16 E18 15AAB1	391524	1195631	P	IVGID
440	391456119563000	90 N16 E18 15DBD1	391456	1195630	P	IVGID
441	391158119555001	90 N15 E18 02BBDA1	391158	1195550	N	USGS
442	391038120090001	90 N15 E17 06BCC1	391038	1200900	N	USGS
443	391031120075901	90 N15 E17 05ABBC1	391031	1200759	N	USGS
444	390935120084001	90 N15 E17 07CADB1	390935	1200840	N	USGS
445	390906120125401	90 15 E16 16ACB1	390906	1201254	N	USGS
446	390904119554201	90 N15 E18 23CCC1	390904	1195542	N	USGS
447	390902120090301	90 N15 E17 18BCB1	390902	1200903	N	USGS
448	390748120100701	90 N15 E16 24CBCD1	390748	1201007	N	USGS
449	390745119563401	90 N15 E18 27DCC1	390745	1195634	N	USGS
450	390743119563101	90 N15 E18 27DCC2	390743	1195631	N	USGS
451	390643119563201	90 N14 E18 03ABB1	390643	1195632	N	USGS
452	390604119564201	90 N14 E18 03CDA1	390604	1195642	N	USGS
453	390542119562101	90 N14 E18 10ADB1	390542	1195621	N	USGS
454	390541119562501	90 N14 E18 10ABD1	390541	1195625	N	USGS
455	390539119561001	90 N14 E18 10ADA1	390539	1195610	N	USGS
456	390510120094101	90 N14 E16 01CADD1	390510	1200941	N	USGS
457	390354120080701	90 N14 E17 18AADB1	390354	1200807	N	USGS
458	390352120090201	90 N14 E17 18BBCA1	390352	1200902	N	USGS
459	390347119562501	90 N14 E18 15DCA1	390347	1195625	N	USGS
460	390301120072000	90 N14 E17 20DB01	390301	1200720	P	CDHS
461	390159120072801	90 N14 E17 29BDA1	390159	1200728	N	USGS
462	390157120070501	90 N14 E17 29ADC1	390157	1200705	N	USGS
463	390132120072001	90 N14 E17 29DCD1	390132	1200720	N	USGS
464	390112119541201	90 N13 E18 01ACCA1	390112	1195412	N	USGS
465	390100119560000	90 N13 E18 03	390100	1195600	P	NBCHP
466	390037119565001	90 N13 E18 10BAB1	390037	1195650	N	USGS
467	390030119564701	90 N13 E18 10BADC1	390030	1195647	N	USGS
468	390027119565001	90 N13 E18 10BDB3	390027	1195650	N	USGS
469	390025119564601	90 N13 E18 10BDA1	390025	1195646	N	USGS
470	390022119565201	90 N13 E18 10BDBD1	390022	1195652	N	USGS
471	385909119532801	90 N13 E19 18CDB1	385909	1195328	N	USGS
472	385902119571301	90 N13 E18 16CCC1	385902	1195713	N	USGS

Appendix B. Selected ground-water sites with available nutrient and pesticide analyses for the Las Vegas Valley area and the Carson and Truckee River Basins, water year 1970 through April 1990—Continued

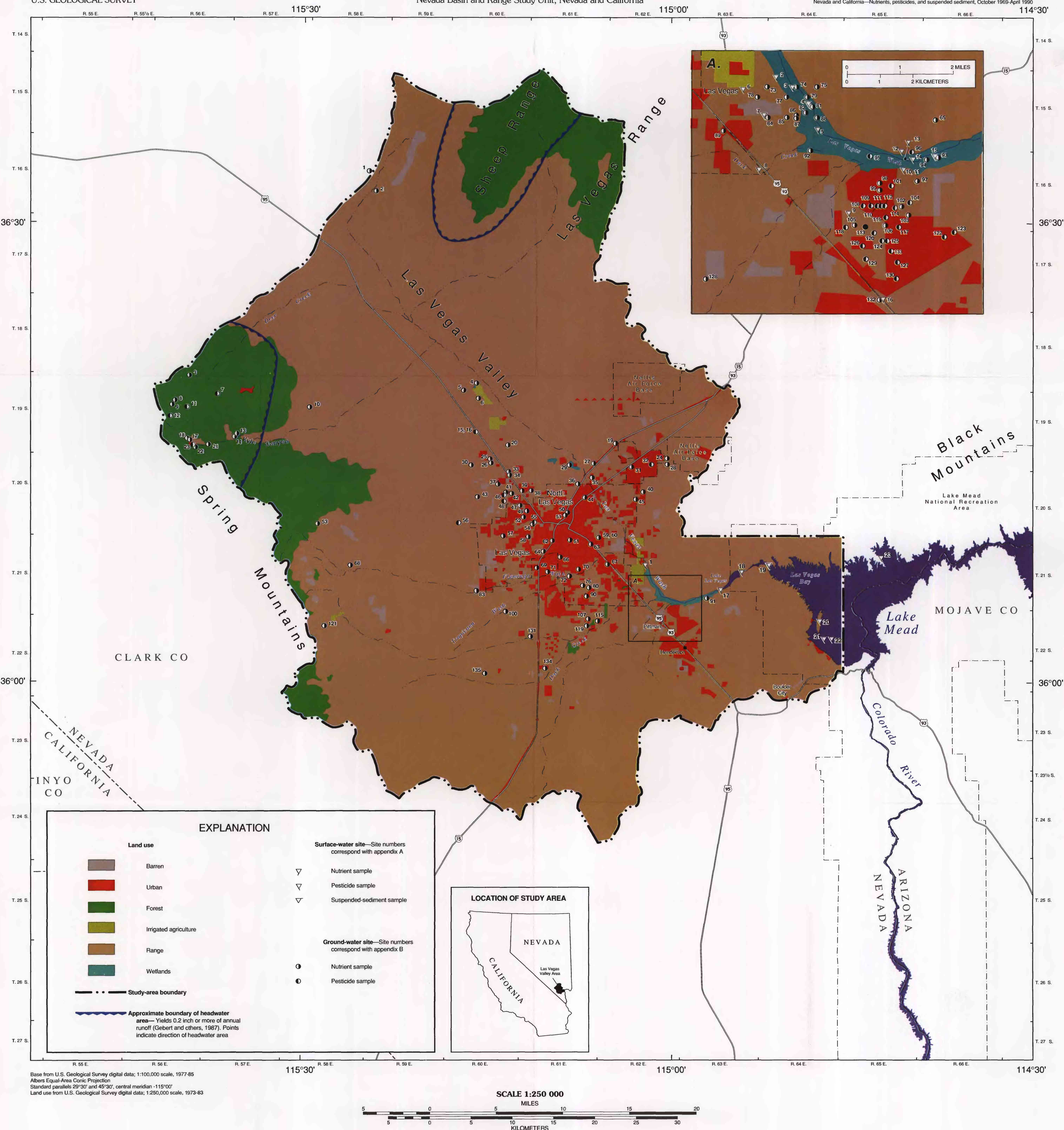
Site number (pls. 1 and 2)	Site identification	Site name ¹	Location		Consti- tuent	Agency
			Latitude	Longitude		
Truckee River Basin—Continued						
473	385859119554001	90 N13 E18 14DCC1	385859	1195540	N	USGS
474	385857119564201	90 N13 E18 22BAA1	385857	1195642	N	USGS
475	385857119555001	90 N13 E18 23ABB1	385857	1195550	N	USGS
476	385842119564601	90 N13 E18 22BDAB1	385842	1195646	N	USGS
477	385839119565601	90 N13 E18 22BCD4	385839	1195656	N	USGS
478	385836119570001	90 N13 E18 22BCD3	385836	1195700	N	USGS
479	385834119565801	90 N13 E18 22BCD1	385834	1195658	N	USGS
480	385824119550401	90 N13 E18 23CBB1	385824	1195604	N	USGS
481	385819119560001	90 N13 E18 23CCB1	385819	1195600	N	USGS
482	385816119563001	90 N13 E18 22DCA1	385816	1195630	N	USGS
483	385813119560401	90 N13 E18 23BBC1	385846	1195604	N	USGS
484	385808119564202	90 N13 E18 22CDD2	385806	1195644	N	USGS
485	385808119564201	90 N13 E18 22CDD1	385806	1195644	N	USGS
486	385735119564500	90 N13 E18 27CA05	385735	1195645	P	CDHS
487	385756119565001	90 N13 E18 27BAC1	385756	1195650	N	USGS
488	385742119565701	90 N13 E18 27BDA1	385748	1195642	N	USGS
489	385640119573500	90 N13 E18 33DB03	385640	1195735	P	CDHS
490	385715119571000	90 N13 E18 33AD01	385715	1195710	P	CDHS
491	385715119564500	90 N13 E18 34BA04	385715	1195645	P	CDHS
492	385720119565000	90 N13 E18 27CD02	385720	1195650	P	CDHS
493	385700119570000	90 N13 E18 34BC03	385700	1195700	P	CDHS
494	385700119560000	90 N13 E18 27CD04	385700	1195600	P	CDHS
495	385700119550000	90 N13 E18 26	385700	1195500	P	NBCHP
496	385658119572501	90 N12 E18 33ADB1	385658	1195725	N	USGS
497	385651119581701	90 N12 E18 03ABA1	385617	1195817	N	USGS
498	385650119572000	90 N13 E18 34CB06	385650	1195720	P	CDHS
499	385630119590000	90 N13 E18 32CD02	385630	1195900	P	CDHS
500	385630119582900	90 N13 E18 32DC01	385630	1195829	P	CDHS
501	385623120030201	90 N13 E17 25CDA1	385623	1200302	N	USGS
502	385605119563308	Lake Tahoe Basin, Wildwood	385605	1195633	N	USEPA
503	385605119563306	Lake Tahoe Basin, Wildwood	385605	1195633	N	USEPA
504	385605119563305	Lake Tahoe Basin, Wildwood	385605	1195633	N	USEPA
505	385605119563302	Lake Tahoe Basin, Wildwood	385605	1195633	N	USEPA
506	385604119563401	Lake Tahoe Basin, Wildwood	385604	1195634	N	USEPA
507	385600120000000	90 N12 E18 04BA01	385600	1200000	P	CDHS
508	385600119580000	90 N12 E18 03AA02	385600	1195800	P	CDHS
509	385600119570000	90 N12 E18 08AC01	385600	1195700	P	CDHS
510	385600119560000	90 N12 E18 01BB01	385600	1195600	P	CDHS
511	385559120001301	90 N12 E18 05AADD1	385559	1200013	N	USGS

Appendix B. Selected ground-water sites with available nutrient and pesticide analyses for the Las Vegas Valley area and the Carson and Truckee River Basins, water year 1970 through April 1990—Continued

Site number (pls. 1 and 2)	Site identification	Site name ¹	Location		Constituent	Agency
			Latitude	Longitude		
512	385542120003900	90 N12 E18 05AB01	385542	1200039	P	CDHS
Truckee River Basin—Continued						
513	385535119555001	Lake Tahoe Basin, a ski trail	385535	1195550	N	USEPA
514	385520119582500	90 N12 E18 03AB01	385520	1195825	P	CDHS
515	385510119584000	90 N12 E18 03BD02	385510	1195840	P	CDHS
516	385500120000000	90 N12 E18 05CA01	385500	1200000	P	CDHS
517	385500120000000	90 N12 E18 05AC01	385500	1200000	P	CDHS
518	385500120000000	90 N12 E18 05BB03	385500	1200000	P	CDHS
519	385500120000000	90 N12 E18 05BB01	385500	1200000	P	CDHS
520	385500120000000	90 N12 E18 05AA02	385500	1200000	P	CDHS
521	385500120000000	90 N12 E18 04BD02	385500	1200000	P	CDHS
522	385500119590000	90 N12 E18 03BA10	385500	1195900	P	CDHS
523	385500119590000	90 N12 E18 03BA08	385500	1195900	P	CDHS
524	385440120025000	90 N12 E18 05DD02	385440	1200250	P	CDHS
525	385435120003000	90 N12 E18 05DC01	385435	1200030	P	CDHS
526	385423119593601	90 N12 E18 09ABC1	385423	1195936	N	USGS
527	385410120002500	90 N12 E18 08AC02	385410	1200025	P	CDHS
528	385410119594000	90 N12 E18 09BD01	385410	1195940	P	CDHS
529	385400120000000	90 N12 E18 09BB06	385400	1200000	P	CDHS
530	385400120000000	90 N12 E18 09BB05	385400	1200000	P	CDHS
531	385400120000000	90 N12 E18 09BB04	385400	1200000	P	CDHS
532	385200120014500	90 N12 E18 29CC03	385200	1200145	P	CDHS
533	385118120010601	90 N12 E18 29CBD1	385118	1200106	N	USGS
534	384806120010800	90 N11 E18 17BC01	384806	1200108	P	CDPR
535	384730120000000	90 N11 E18 17	384730	1200000	P	CDPR

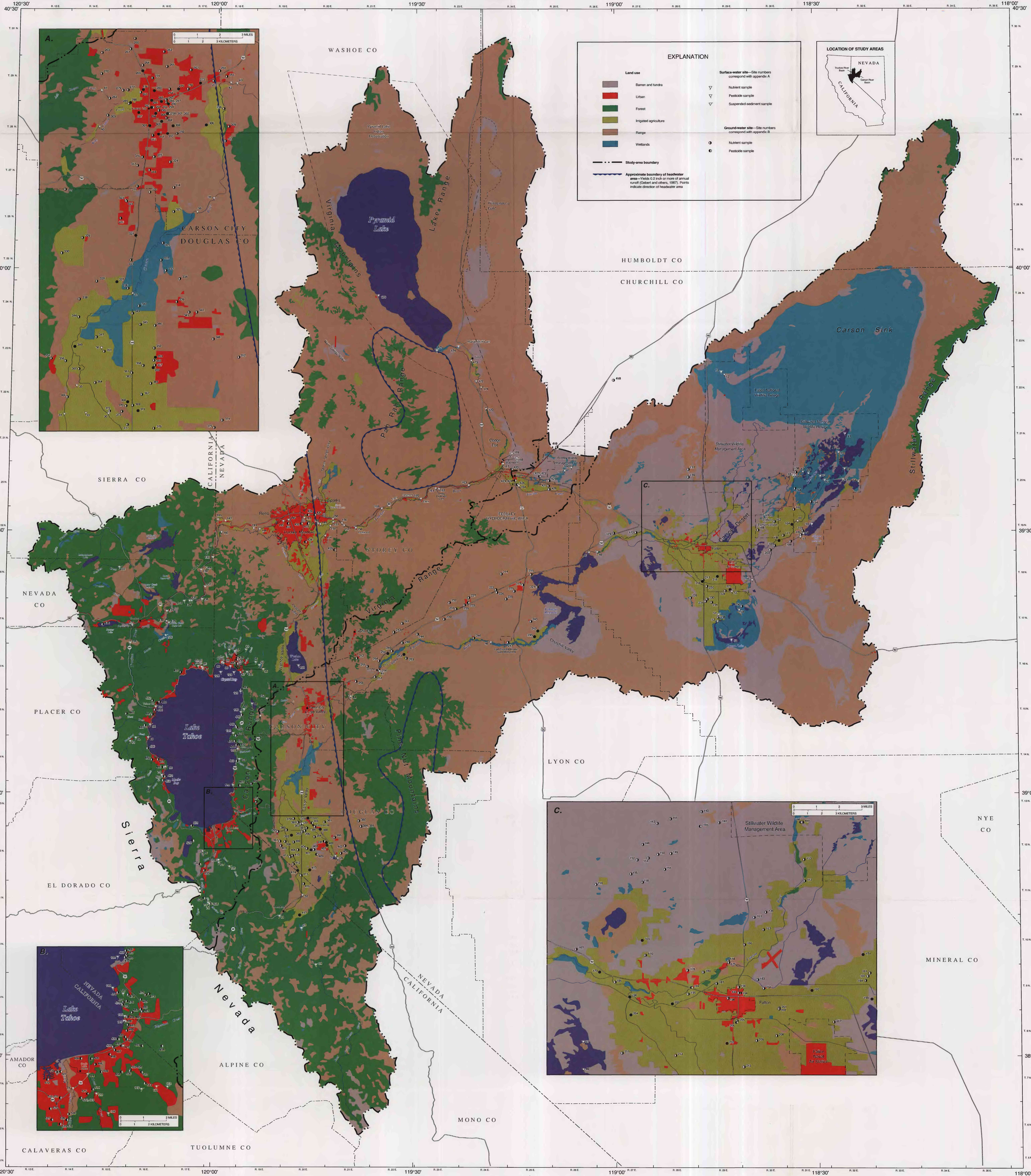
¹ The numbering system for wells and springs used in U.S. Geological Survey Reports for Nevada is based on an index of hydrographic areas (Rush, 1968) and the rectangular subdivision of the public lands referenced to the Mount Diablo base line and meridian. Each site designation consists of up to four units separated by spaces: The first unit is the hydrographic area number. The second unit is the township, preceded by an N or S to indicate location north or south of the base line. The third unit is the range, preceded by an E to indicate location east of the meridian. The fourth unit consists of the section number and letters designating the quarter section, quarter-quarter section, and so on (A, B, C, and D indicate the northeast, northwest, southwest, and southeast quarters, respectively), followed by a number indicating the sequence in which the site was recorded. For example, site 101 N19 E29 08DABC1 is in the Carson Desert of the Carson River Basin (hydrographic area 101), and is the first site recorded in the SW 1/4 of the NW 1/4 of the NE 1/4 of the SE 1/4 of section 8, Township 19 North, Range 29 East, Mount Diablo base line and meridian.

² These sites are in the Fernley Hydrographic Area, which is traversed by the Truckee Canal.



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SAMPLING SITES, LAND USE, AND GEOGRAPHIC INFORMATION, CARSON AND TRUCKEE RIVER BASINS, NEVADA AND CALIFORNIA

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Kathryn C. Kilroy, Stephen J. Lawrence, Michael S. Lico, Hugh E. Bevens, and Sharon A. Watkins
1997